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IoT:Smart Homeusing Zigbee Clustering Minimum Spanning Tree and Particle Swarm Optimization (MST-PSO)

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ABSTRACT

In Smart home environment, appliances are monitored and controlled by sensor nodes. Zigbee Cluster Tree Network is widely used protocol for smart home environment. Minimum Energy consumption and minimum cost path are important issues in this type of networks. Among many solutions proposed by researchers clustering technique provides energy efficiency and less expensive. Clustering technique operates by dividing the network into many sections, each of which has a cluster head (CH). The tasks of cluster head are collection, aggregation and transmission of data to the base station. In this paper, we introduce a new approach for clustering namely Zigbee cluster tree networks based on Minimum Spanning Tree Particle Swarm Optimization (MST-PSO). It aims to extend network lifetime and reduce router dependency in Zigbee protocol. Simulation results show that the proposed method is more efficient compared to protocols such as Zigbee cluster tree in terms of network lifetime and energy consumption.

Keywords:- Zigbee, Clustering, Minimum Spanning Tree, Particle Swarm Optimization.

I. INTRODUCTION

Internet of Things (IoT) vision gives rise to development of innovative applications that integrates well in to familiar traditional digital technologies. IoT intends to communicate among devices autonomously without human intervention and generate integrated data. Innovative applications include smart home, smart transportation, smart healthcare, smart industry, etc. Initially smart home environment was focussed on efficient management of homes with smart devices. However, in recent years smart home environment is extended to smart lighting systems, smart home ambience. High end security systems, heating control systems, remotely controllable devices, smart device management, enhance energy consumption and so on.

Smart homes typically evoke the vision of The Jetsons' robot maid or refrigerators ordering milk from Amazon, but they also offer possibilities for energy and cost savings, greater efficiency of home through automation as well as improved home security[1]. Smart homes have the potential to provide for consumers' growing expectations of convenience, sustainable living, low on expenditure, safety and security.

ZigBee is an open wireless standard designed to provide foundation for the Internet of Things (IoT) by enabling everyday objects to work together. ZigBee technology is used often to connect things because of its characteristicssuch as network resilience, interoperability and low powerconsumption. In ZigBee mesh connectivity, if an object is faulty or drained in energy the network connectivity will not be interrupted instead other objects will continue tocommunicate. Objects using Zigbee are interoperable, as thestandard specifies how objects interoperate.

Theoutline of this paper is as follows.In section 2, related literature such as LEACH, CHEF and PSO-MV technique are discussed. Section 3 describes the overview of ZigBee and PSO which supports protocol stack and cluster tree network. Section 4 describes the experimental setup. Section 5 contains result and analysis. Section 6 concludes with and future challenges.

II. RELATED WORK

ZigBee and IEEE 802.15.4 are two standards-based protocols for providing the network infrastructure required for wireless sensor network applications. 802.15.4 defines the physical and MAC layers, and ZigBee defines the network and application layers. Weighted Centroid Localization (WCL) provides a fast and easy algorithm to locate devices in wireless sensor networks. The algorithm is derived from a centroid determination which calculates the position of devices by averaging the coordinates of known reference points [2].

LEACH [3]protocol is the oldest of the clustering algorithms in WSN. It is ahierarchical method in which the routing method uses a single step. Its main objective is tomaximize network lifetime, and distribute energy consumption across all network nodes. Each node sends the received information to cluster heads and cluster heads in turn transmitthedata to the base station. All data processing duties such as integration and collection is performedlocally by cluster head(CH).

Nodes that have been cluster heads cannot become cluster heads again for P rounds, where P is the desired percentage of cluster heads. Thereafter, each node has a 1/P probability of becoming a cluster head in each round. At the end of each round, each node that is not a cluster head select the closest cluster head and joins that cluster. The cluster head then creates a schedule for each node in its cluster to transmit its data.

CHEF[2]protocol [4] cluster head selection mechanism uses fuzzy logic. CHEF algorithm obtains chance from two fuzzy set namely: residual energy of a node and total distance between a node with other nodes that are located at a radius. CHEF can overcome the defects of LEACH. The sensor node which has more residual energy has better chance of becoming cluster heads.

The algorithm is performed in three steps:

1. CH selecting

2. Clusters formation

3. Data transmission

The algorithm uses two level cluster heads (primary and secondary).Secondary cluster heads with other members which are located in one cluster communicate andafter data aggregation transmit them to primary cluster heads and primary cluster heads route datato base station. The data which is sent to base station reduce energy consumption significantly butthere is a lot of overhead in the election of primary and secondary cluster heads which affects thenetwork lifetime.

PSO-MV[7]protocol [5] as well is based on PSO method, and since energy consumption in cluster head is higher than other nodes, the purpose of the approach is energy balance. In thePSO-MV method, the 2 nodes are selected as cluster heads that is a node as main cluster heads(MCH) and other as (VCH).MCHis responsible for data collecting and transmission and VCH is responsible for inter-cluster communications or intra - cluster communications to base station (BS).

The **EECS[8]**protocol [6] focuses to solve the problem of clusters distance from BS. In fact, the cluster which is far from the base station needs more energy consumption for data transmission.For this reason ,of dynamic size to cluster is determined due to the distance of the cluster frombase stations. This algorithm makes a more uniform distribution of energy in the whole network which leads to increasing network lifetime.

A.Proposed Work

MST-PSO cluster tree network is proposed to solve problem of energy consumption and path cost in smart home scenario. Although Zigbee cluster-tree topology has medium bandwidthMST finds the minimum distance between nodes and discover minimum spanning tree and PSO algorithm helps to select the cluster head(CH) based on node's residual energy. Cluster head is directly connected to coordinator. Hence CH gathers data from neighbour nodes and sends them to the coordinator.

III.OVERVIEW OF THE ZIGBEE AND PSO

A.Zigbee Network

ZigBee is a standards technology that addresses the unique needs of remote monitoring and control sensor network applications[7]. The ZigBee standard was developed to address the following needs: Low cost, Secure, Reliable and self healing, Flexible and extendable, Low power consumption, Easy and inexpensive to deploy, Global with use of unlicensed radio bands, integrated intelligence for network set-up and message routing.

1) ***Zigbee Devices:***ZigBee networks include the following device types:Coordinators, Routers and End devices.Coordinator device controlsthe entire network Fig. (1). The coordinator stores information about the entire network which acts as the Trust Centreof thenetwork. It also serves asrepository for security keys purpose. Router devices focus on extending network coverage area. They dynamically allocate route that are with obstacles andprovide backup routes in case of network congestion or device failure. Routers can interact with the coordinator, other routers and also support child devices.End Devices are also known as child device but childdevice is not always known as an end device. End devices can transmitor receive a message, but cannot perform any routingoperations. They must be connected to either the coordinatoror a router, and do not support child devices.
2) ***Type of Networks:***Zigbee supports star topology, clustertopology and mesh topology. Cluster tree based topology iseffective for WSNs. But it has limitations such as routing and poorbandwidth utilization.In a tree structure, any link failure will suspend datadelivery completely and the recovery operation will incur considerable overhead. The topology also prevents the use ofmany potential routing paths, which means, that a considerableamount of bandwidth cannot beutilized.

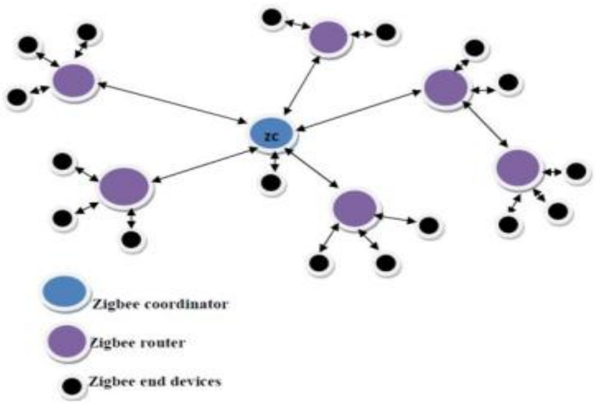


Figure 1: Zigbee devices and Network type

As shown in figure 1, the end devices are directly connected to the router. End devices transfer the data to router and receive acknowledgement. Routers collect the data sent by end nodes and transfer the data to coordinator. Coordinator aggregates the data and sends it to the base station.

B.Particle Swarm Optimization (PSO)

PSO is originally attributed to Kennedy, Eberhart andShi and was first intended for simulating social behaviour asa stylized representation of the movement of organisms in abird flock or fish school[8]. The algorithm was simplified to perform optimization. An extensive survey of PSOapplications is made by Poli. In computer science, Particle Swarm Optimization (PSO) is a computational method thatoptimizes a problem by iteratively trying to improvea candidate solution with regard to a given measure of quality.PSO optimizes a problem by having a population of candidatesolutions, here dubbed particles, and moving these particles around in search-space according to simple mathematical formula over the particle's position and velocity. Eachparticle's movement is influenced by its local best knownposition and is also guided toward the best known positions inthe search-space, which are updated as better positions arefound by other particles. This is expected to move the swarmtowards the best solutions.

$$v_{id}^{i+1} = w.v_{id}^{t} + c_1.\emptyset_1.(p_{id}^{t} - x_{id}^{t}) + c_2.\emptyset_2.(p_{gd}^{t} - x_{id}^{t}) \quad (1)$$

v_{id}^{t}: Component in dimension d of the i^{th} particle velocity in iteration t.

x_{id}^{t}: Component in dimension d of the i^{th} particle position in iteration t.

c_1,c_2: Constant weight factors.

p_{id}^{t}: Best position achieved so long by particle i.

p_{gd}^{t}: Best position found by the neighbors of particle i.

$\emptyset_1, \emptyset_2$: Random factors in the [0,1] interval.

w: Inertia weight.

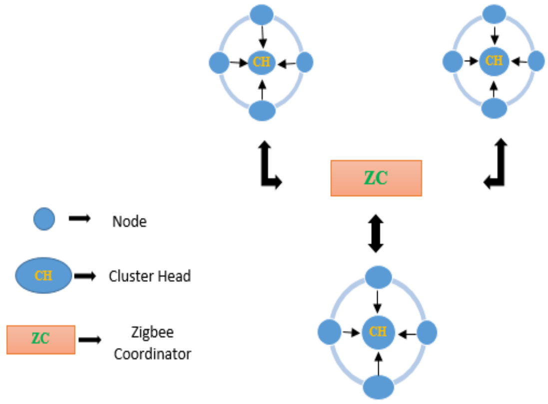


Figure 2: MST-PSO Zigbee in Smart Home

In Fig 2, modified Zigbee cluster tree network is shown, where routers are removed from the network. The cluster head (CH) in MST-PSO work as routerto gather information from cluster and then send to coordinator. Selection of Cluster head from end nodes will be change periodically.

IV.EXPERIMENTAL SETUP

This section discusses proposed methodology for Zigbee cluster tree network. It contains MST using Prim's algorithm, and PSO algorithm with flowchart.

A. Minimum Spanning Tree

MST method is usedto find minimum distance between nodes in the Zigbee netwrok. MST contain Kruskal's algorithm and Prim's algorithm[9] to form spanning tree. Here we use Prim's algorithm to find minimum distance between each nodes.

In Prim's algorithmis explained below. At the initialization phase a tree with a single vertex is chosen arbitrarily from the graph.Grow the tree by one edge: of the edges that connect the tree to vertices not yet in the tree, find the minimum-weight edge, and transfer it to the tree. Repeat until all vertices are in the tree. The result is explained in Figure 3.

Algorithm : 1 Prim's algorithm

T = a spanning tree containing a single node s;

E = set of edges adjacent to v;

while T does not contain all the nodes

remove an edge (v, w) of lowest cost from E

if w is already in T then discard edge (v, w)

else

add edge (v, w) and node w to T

add to E the edges adjacent to w

End if

End while

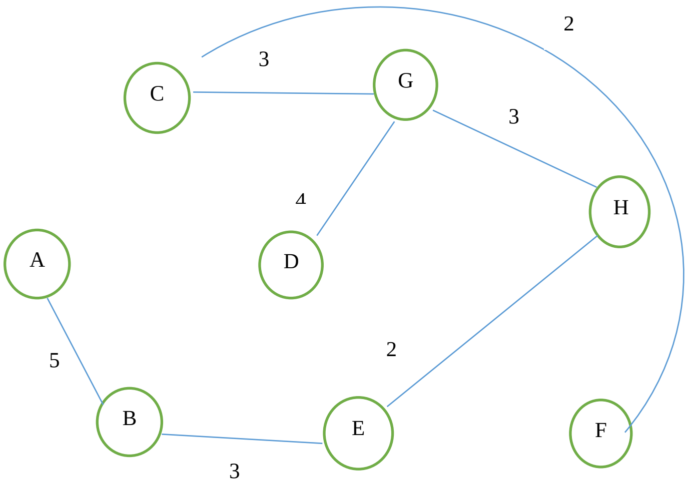


Figure 3: Prim's MST

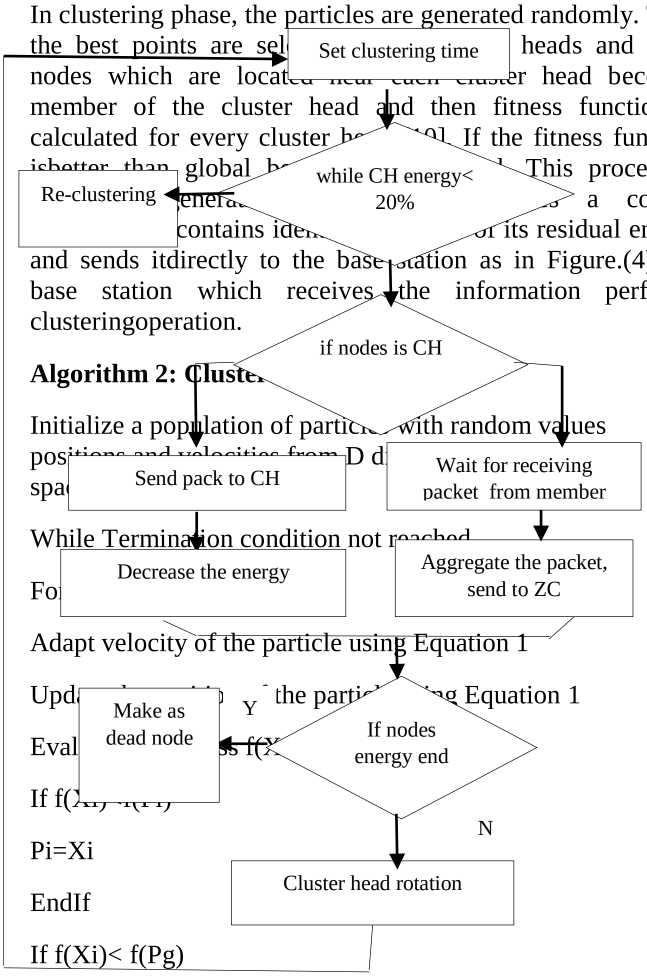
In Figure 3, using prim's algorithm to find minimum spanning tree: (1) Start with any nodes here start from D. (2) updated distance of adjacent nodes, unselected nodes. (3) Select node with minimum distance G. (4) Repeat step 2 until all vertices are in tree.

Table 1: Cost of MST

	K	d_v	p_v
A	T	4	H
B	T	4	C
C	T	3	D
D	T	0	–
E	T	2	F
F	T	3	C
G	T	2	D
H	T	3	G

In Table 1, shows the node added to Spanning tree minimum distance without loop, the total cost of minimum spanning tree $\sum dv$=21.

B.Cluster Setup



In clustering phase, the particles are generated randomly. Then the best points are sel[illegible] heads and other nodes which are locat[illegible]er head becomes member of the cluster head and then fitness function is calculated for every cluster he[illegible]0]. If the fitness function isbetter than global b[illegible]. This process is [illegible] a control [illegible]contains ide[illegible] of its residual energy and sends itdirectly to the base station as in Figure.(4).The base station which receives the information performs clusteringoperation.

Algorithm 2: Cluste[illegible]

Initialize a population of partic[illegible] with random values positions and velocities from D d[illegible] spa[illegible]

While Termination condition not reached

Fo[illegible]

Adapt velocity of the particle using Equation 1

Upd[illegible] the parti[illegible]g Equation 1

Eval[illegible]ss f(Xi)

If f(Xi)<f(Pi)

Pi=Xi

EndIf

If f(Xi)< f(Pg)

Pg=Xi

EndIf

EndFor

EndWhile

C.Data Transmission Phase

Once Cluster formation and cluster heads election of each cluster is over, data transmission phase begins wherein data is sent to cluster head from the neighbour nodes. Data can be transmitted by the normal node to corresponding cluster heads. In this phase, each normal node is connected to the nearest cluster head. Each node sends its data at allocated interval to cluster head in the form of data message. The cluster head aggregates and transmit data towards Zigbee coordinator.

Figure 4: Data transmission in MST-PSO

Figure 4, shows the flow chart of data transmission phase in MST-PSO algorithm

V. RESULTS AND ANALYSIS

The Simulation using MAT-Lab IDE, analyses of old zigbee cluster tree network and their energy efficiency

A.Energy Efficiency

Energy efficiency of the proposed MST-PSO zigbee cluster tree network is calculated by formula 2.Here, *n* is a total number of nodes, *m* is total number of routers, *l* is a total number of Coordinators, *ed* is end devices energy, *rd* is router energy, *cd* is coordinator energy

In old zigbee cluster tree network the energy taken by network calculated as follows:

$$e = \sum_{i=1}^{n} ed + \sum_{j=1}^{m} rd + \sum_{k=1}^{l} cd \quad (2)$$

In MST-PSO zigbee cluster tree network the energy calculated as:

$$e = \sum_{i=1}^{n} ed \quad (3)$$

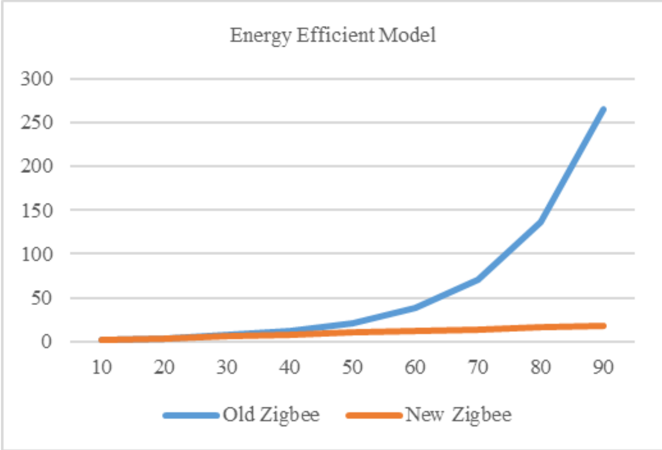


Figure 5: Energy Efficiency Comparision

Figure 5, shows the chart representation of old zigbee and proposed zigbee energy efficient comparision.

Table 2: Energy used for Old Zigbee and New Zigbee

Nodes	Router	Old Zigbee	New Zigbee
10	2	2	2
20	4	4	4
30	8	7	6
40	16	12	8
50	32	21	10
60	64	38	12
70	128	71	14
80	256	136	16
90	512	265	18

Table 2, show the energy consumption Old Zigbee and New Zigbee network. The nodes and router energy calculated as Old Zigbee (0.1,0.5) per each node and router, in New Zigbee model node energy calculated as (0.2) per each node.

B.MST-Partical Swarm Optimization in Zigbee

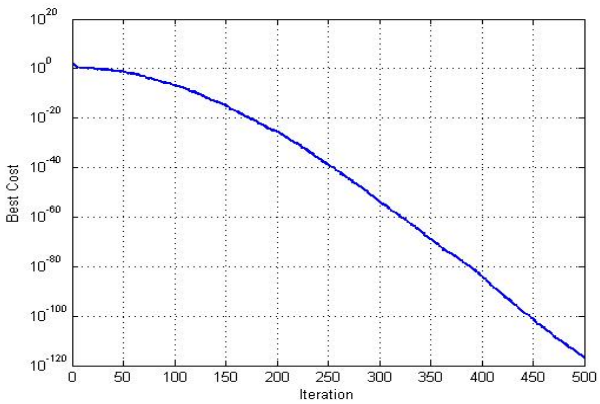


Figure 6: MST-PSO for 500 iteration

Figure 6 shows MST-PSO algorithm output for 500 iteration with their best cost.

VI. CONCLUSION

In old zigbee cluster tree network the increase in number of routers will increase power consumption. Forimproving efficiency of network a new approach of network arrangement is proposed and implemented that is also known as a MST-PSO zigbee cluster tree organization.The performance of the network is assessed by energy efficiency, packet transmission ratioand path cost. After implementing MST-PSO cluster tree network, we conclude that in our proposed network, power consumption is low even when the number of nodes increases. Comparing to the old network, efficient packet transmission rate and low path cost are also achieved. However, our proposed work consumes higher implementation timecompared to the old network. According to the results the newlyarranged network performs well than old network.Future enhancement of proposed system is that the end devices itself select the cluster head instead of base station.

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