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A Non Threshold Based Cluster Head Rotation Scheme for IEEE 802.15.4 with Clustering Protocol and STR Algorithm

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Abstract: In recent years, wireless networking plays a prominent role because of its easy installation and flexibility. Among the various wireless domains, Zigbee based Wireless Dynamic Sensor Networks (WDSN) pose a good support to the dynamics that arise when the nodes are induced with mobility. Clustering protocols specify the topology of the hierarchical non-overlapping cluster of sensor nodes. LEACH (Low Energy Adaptive Clustering Hierarchy) protocol relies on selecting the CHs randomly in each transmission round. Hence the clustering technique and STR, route the information through the shortest path paving the way for enhanced average residual energy and Packet Delivery Ratio (PDR). Cluster head rotation algorithm is the selection of Cluster Heads (CHs). The three methods are combined to best performed in WSNs. The simulation results show that the network performance improved and the energy consumption of network has been balanced.

Keywords —Zigbee; WDSN; clustering; cluster head; residual energy; STR.

I. INTRODUCTION

Wireless Sensor Networks (WSNs) are utilized for different applications such as remote environment monitoring, military, surveillance etc in order to sense physical parameters such as temperature, pressure, humidity etc. Wireless Sensor Network can be defined as a network

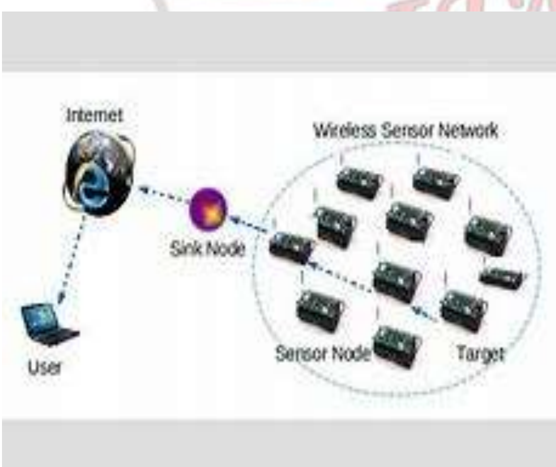

Fig.1.1 WSN

with massive number of tiny, less expensive sensor devices that have the capability to detect; measure and interact with other devices in order to collect local information and to make an overall decision about the physical ambience. The sensor network consists of sensor field, sensor nodes, sink and task manager as illustrated in fig 1.1.

Architecture

Sensor field is the field wherein the sensor nodes are positioned. The sensor nodes are the essential components in the sensor network. These are responsible for gathering the data and then forwarding the same to the sink. Sink is the point of data gathering and its task is to receive; process and store the data from other sensor nodes.

The centralized control point within the network is the task manager whose purpose is to draw the information from the network and distribute control information back into the network. A small variant of WSN is WDSN wherein the nodes are mobile in nature. Since the nodes are dynamic; various features such as network formation, capability to organize and reorganize, discerning the route and handling the communication among the mobile nodes have to be considered. These features are supported by Zigbee based WDSN.

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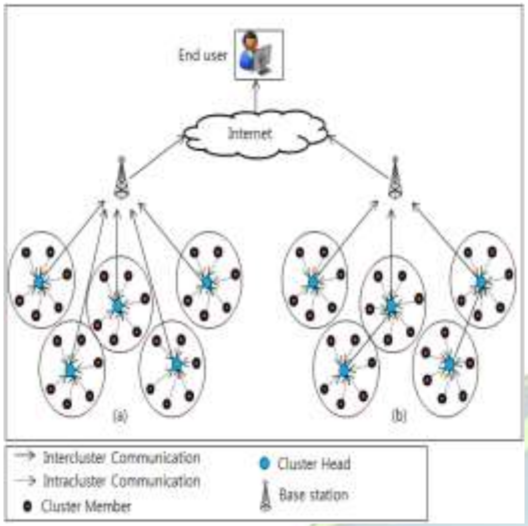

Fig.1.2 WSN with Cluster

IEEE 802.15.4 is the IEEE standard that defines the physical layer and MAC layer for Low-Rate Wireless Personal Area Networks (LR-WPANs). LR-WPANs are otherwise known as Zigbee networks. Zigbee technology is very widely used as they are easy to install, reliable, self-configurable and self-healable networks.

Wireless Sensor Network (WSN) applications render it impossible to charge or replace the battery of sensor nodes. Therefore, optimal use of node energy is a major challenge in wireless sensor networks. Clustering of sensor nodes is an effective method to use the node energy optimally and prolong the lifetime of energy constrained wireless sensor network. In this paper, we propose a location based protocol for WSN- supporting an energy efficient clustering, cluster head selection/rotation and data routing method to prolong the lifetime of sensor network. Proposed clustering protocol ensures balanced size cluster formation within the sensing field with least number of transmit- receive operations. Cluster head rotation protocol ensures balanced dissipation of node energy despite the non-uniform energy requirements of cluster head and sensor nodes in a cluster. The cluster head rotation protocol has been proposed to achieve the balanced energy consumption among the nodes within the cluster thus prolonging the lifetime of network Simulation results demonstrate that proposed protocol prolongs network lifetime due to the use of efficient clustering, cluster head selection/rotation and data routing.

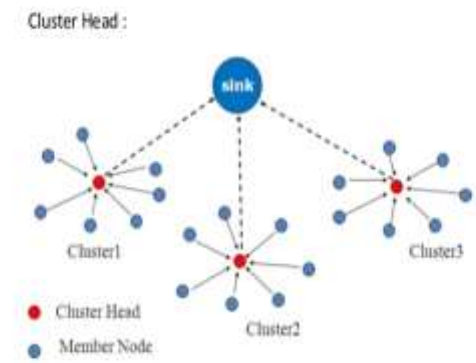

Fig.1.3 Cluster Head

Zigbee supports multiple hop transmissions-receptions and also routing between the mobile sensor nodes. Zigbee based WDSN have the following benefits:

• Zigbee protocol cuts down the energy drawn by the nodes, as they make the nodes to enter into a sleep state when the sensor nodes do not transmit or receive/remain idle for a prolonged time.

• The nodes in WDSN require constant restructuring and reformation of routes and topology. Zigbee protocol has inherent functionalities for discerning the network and for routing the information among the nodes.

In the Zigbee based WDSN, the sensor nodes are mobile and the energy consumed by the mobile nodes varies with the distance. The Received Signal Strength Indicator (RSSI) algorithm is used to calculate the distance from the strength of the received signal. The RSSI is best suited for communication through wireless media. In the RSSI algorithm, the strength of the received signal is inversely proportional to the squared distance between the transmitter and the receiver. Hence it can be used for measuring the wireless link quality. The RSSI can be effectively used to identify the packet reception rate in the wireless network. In order to analyze the packet reception rate using RSSI, a threshold level is maintained. If the calculated received signal strength value overlaps with the threshold region, then the number of packets received successfully will be less. On the other hand, if the calculated received signal strength value does not overlap with the threshold region, then the number of packets received successfully will be high indicating a better network performance.

WSNs pose several advantages but they do suffer from few limitations and also few authors have proposed several protocols for existing WSN networks. Hence in this paper an effort is made to tackle a limitation which is of major consideration in WDSN (i.e) energy consumption. This paper utilizes a technique which could effectively cut down the energy drawn by the nodes and also enhances the Packet Delivery Ratio (PDR). The rest of the paper is summarized as follows: Section II discusses the existing work. Section III presents a detailed description of proposed work. Section IV analyzes the performance of proposed work through simulation results. Finally, Section V concludes the paper.

II. Existing Work

The existing work considers Zigbee based WDSN with non-clustered technique. For routing the packets among the nodes in Zigbee wireless network, various routing schemes such as ZTR (Zigbee Tree Routing) and STR (Shortcut Tree Routing) have been proposed. ZTR is proposed for Zigbee devices that are limited in their resources. It routes the packets on a multi hop routing path from source to the destination.

ZTR suffers from a serious limitation. That is, even when the destination node is at one hop distance, the packets will be routed to destination only on a parent child relationship. To overcome the limitation of ZTR, STR protocol is proposed. The merits of ZTR are retained in STR but it identifies the neighbor node as its next destination node by discovering the nodes that are at 1-Hop distance.

The existing work utilizes Shortcut Tree Routing (STR) algorithm to route packet among the nodes. STR algorithm intends to reduce the cost incurred for routing while routing the packets between the source and the destination. The STR algorithm is utilized to identify the optimal next hop node that has the least remaining hop counts to the destination. The key features of STR include; low memory consumption and no route discovery overhead.

In the existing work, total number of mobile sensor nodes considered for simulation is 125 and they are deployed randomly. Each node has an initial energy of 5J. The existing work performance is analyzed through metrics such as average residual energy and PDR by differing the number of nodes from 25 to 125 and range from 45m to 125m. The wireless sensor networks are mostly deployed in remote and hazardous locations, where manual monitoring is very difficult or almost impossible. Due to deployment of wireless sensors in unattended harsh environment, it is not possible to charge or replace their batteries. Therefore, energy efficient operation of wireless sensors to prolong the lifetime of overall wireless sensor network is of utmost importance. Due to their low power radio, wireless sensor nodes cannot transmit the data to large distance in single hop, which makes multi-hop communication essential in case of real life deployment. However, in multi-hop cases, if the energy consumption of sensor nodes is not managed properly it may create energy-hole problem in the network [3]. In literature, a number of protocols have been proposed to manage and reduce the energy consumption of sensor nodes [1]. Grouping sensor nodes into clusters has been widely used to achieve this objective. In clustered networks, one of the sensor nodes is elected as cluster head for each cluster. Sensor nodes in each cluster transmit data to their respective cluster head and the cluster head in turn forwards the data after aggregation/fusion to sink node through single/multi-hop transmission. LEACH is one of the most popular distributed single-hop clustering protocols [5]. In this protocol, the clusters are formed, based on received signal strength. The role of cluster head is periodically rotated amongst the sensor nodes present in the cluster to ensure balanced energy consumption of sensor nodes. This algorithm becomes very inefficient in case of large area sensor networks due to single hop communication of cluster heads to the sink. In this paper, we propose an energy efficient protocol consisting of clustering, cluster head selection/rotation and data routing method to prolong the lifetime of sensor network. In proposed protocol, clusters are formed only once during the lifetime of sensor network, which results in substantial saving of energy.

III. Proposed Work

The proposed work aims at enhancing the performance of existing work by introducing the clustering technique. Among the various protocols proposed for WSNs, hierarchical protocols outperform other protocols since they augment the network lifetime, reduce the energy dissipated by the sensor nodes and cut down the number of communication messages among the sensor nodes. Hierarchical protocols are cluster based protocols (i.e) the sensor nodes in the network are grouped into clusters. The role of cluster-head in an IEEE 802.15.4 cluster tree network is to aggregate data from various devices in the cluster and cumulatively transmit to the PANC (Personal Area Network Coordinator). This is an energy efficient way of sending data compared to individual reporting of devices independently. Cluster-head coordinators expend more energy compared to other coordinators in the cluster as they have to remain active for longer duration and carry out tasks like aggregation and transmission. Therefore this role of a cluster head has to be periodically rotated among different coordinators to prevent exhaustion of a particular coordinator's energy and to extend the overall network lifetime.

Wireless sensor networks (WSNs) base the cluster-head rotation decision on threshold of available residual-energy in a coordinator. A non-threshold based cluster-head rotation scheme that makes a rotation decision based on network lifetime. It considers the residual energy, transmission cost and aggregation cost from associated coordinators and end-devices in synchronized IEEE 802.15.4 cluster-tree networks.

Low Energy Adaptive Clustering Hierarchy protocol (LEACH) is an example of hierarchical protocol. It effectively cuts down the energy consumed by the nodes in the network. In the LEACH protocol, the node with least energy consumption is made to be the cluster head of that particular cluster. Among various LEACH protocols such as Centralized- LEACH, Modified LEACH, Multi hop LEACH, Two level LEACH, Vice LEACH etc, Optimization Low Energy Adaptive Clustering Hierarchy (O-LEACH) [3] finds an alternate way to cut down the energy required by the sensor nodes for establishing communication. In the O-LEACH, the sensor node with the highest residual energy is chosen as the cluster head of that particular cluster. In the proposed work, the O-LEACH protocol is modified and utilized. Wireless sensor networks (WSNs) base the cluster-head rotation decision on threshold of available residual-energy in a coordinator. A non-threshold based cluster-head rotation scheme that makes a rotation decision based on network lifetime. It considers the residual energy, transmission cost and aggregation cost from associated coordinators and end-devices in synchronized IEEE 802.15.4 cluster-tree networks.

CH rotation scheme that addresses the limitation of the previous work by considering a multi-hop cluster-tree network topology. Besides, the proposed mechanism considers network lifetime for CH rotation without any pre-determined and fixed rounds, and thresholds for CH rotation. The coordinator that prolongs network lifetime is selected as the CH in each cluster. The main contributions of this project are summarized as follows.

- Cluster-head rotation mechanism for multi-hop IEEE 802.15.4 cluster-tree network using coordinators' lifetime is proposed.
- Network lifetime is evaluated considering the residual energy, transmission cost towards PAN coordinator and aggregation cost from the associated devices.

Lifetime Based CH Rotation Algorithm

In general, the lifetime of a coordinator device can be defined as the time span from its deployment to the time instant when its battery dies. On the other hand, network lifetime is the duration from network initiation to the instant when the network is unable to perform its normal operations, which may be application specific. For a cluster, when the CH dies, it renders the entire cluster orphaned in a cluster tree topology. Hence, cluster lifetime can be defined in terms of the lifetime of the of the CH coordinator. The lifetime of a coordinator in an IEEE 802.15.4 cluster tree network topology depends on the following factors:

- The current remaining energy of the device (i.e.,Eremaining).
- Power consumed on aggregation of data from all the associated coordinators and devices, (i.e., Paggregation).
- The power consumed on transmission of aggregated data
- To the next cluster coordinator,(i.e., Ptransmission).
- A constant continuous power consumption for the normal
- network operations, (i.e. Pconst-power). This includes various factors such as synchronization, duty-cycling, cluster formation, association, dissociation, beacon management, PAN maintenance, overhead for various control, and ACK frames.

Paggregation=

$$\sum_{i=1}^{n} rnchild \times Prec, \qquad \text{-------------(4.1)}$$

Where, rnchild is the number of frames generated/transmitted by the nchildth device. For simplicity, we consider that all the devices generate data frames at a rate of η per unit time. Therefore,(4.1) can be re-written as

$$Paggregation = \eta \times nchild \times Prec. \qquad \text{--------------(4.2)}$$

The aggregation cost from a coordinator Ci to another coordinator Cch is given by,

$$Paggr\text{-}Ci\text{-}Cch = hi \times Paggregation,$$

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---------------(4.3)

Where hi is the hop count from the sensing device (connected to the Ci) to the coordinator Cch.

The transmission cost for transmitting the aggregated data to the coordinator in the next cluster at hc hops away is expressed as,

$$P_{transmission} = \eta \times n \times hc(P_{tx}),$$ ----------------(4.4)

The lifetime, i.e, ζ, can be expressed as

$$\zeta = \frac{E_{remaining}}{P_{const-power} + P_{aggregation} + P_{transmission} + P_{CH-overhead}}$$ ------------(4.5)

Note that the lifetime in (4.5) can be easily extended by considering other energy consumption sources considered in Pconst-power. The CH rotation overhead, PCH-overhead is considered while selecting a new CH.

Algorithm:

1. Receive Eremaining, Pconst-power, Paggregation, Ptransmission from each of the coordinator;
2. Compute PCH-overhead for each coordinator using hop distance;
3. Compute network lifetime for each of the corresponding coordinator;
4. Find a device i with longest network lifetime using (5);
   if (LifetimeCH ≤ Lifetimei) then
5. CH=i;
   Else
6. Continue with present CH;

End

IV. Results And Discussion

We considered a cluster-tree Parameters Values Frequency band 2.4GHz Maximum data rate 250kbps Number of nodes 11 Transmission radius 50m Transmission Time 600 s Initial Energy 1J Energy consumption to receive a frame 0.003J Energy consumption to transmit a frame 0.006J Energy consumption during sleep-state 0.000030J network that consists of 71 nodes (31 coordinators and 40 end- devices) forming 7 clusters over an area of 1000m × 1000m. The results shown herein are relative and therefore the choice of values for parameters like energy spent to transmit and receive and the energy spent in sleep state by a device do not alter results. The simulation parameters considered in the experiments are summarized in compares the lifetime of the network among fixed CH topology as in IEEE 802.15.4 standard, LEACH and the proposed mechanism. It depicts the network lifetime of an IEEE 802.15.4 cluster-tree topology for scenarios, viz., a) fix CH (as per the standard), b) LEACH mechanism, and c) proposed non-threshold based CH rotation. It is observed that when the CH is fixed, a single coordinator consumes higher energy compared to other homogeneous coordinators. As the lifetime of a cluster solely depends upon the lifetime of the CH, the effective network lifetime decreases parallel to the battery of the CH. On the other hand, LEACH rotates the CH among all the coordinators in a probabilistic manner, without considering the overhead of any such selection in terms of transmissions, aggregation and residual energy of the coordinators. Hence, such a compulsory rotation periodically is not always optimum for the network lifetime. The proposed non-threshold mechanism selects a new CH whenever, the network lifetime can be improved by such a rotation. This also ensures one particular coordinator from exhausting its battery faster than other coordinators. We observe a significant increase (by 28% over fixed CH scheme) in network lifetime when the proposed mechanism is used. we compare the residual energy of cluster 7 of fig between fixed CH scenario, LEACH and the proposed mechanism. We consider a small initial energy of 1Jouleand consider the relative difference is residual energy. The figure illustrates the energy conserved by the CH of the cluster. Initially, the residual energy of the CH is similar in all three scenarios. However, in the proposed scheme and LEACH, new CHs are selected over time. For LEACH, newly selected CH may have higher residual energy than the previous CH, as selection occur every round in a

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probabilistic manner. In the proposed scheme, the present CH identifies a new CH, based on transmitted parameters, that definitely improves lifetime of the cluster. Thus, over time, the proposed mechanism rotates the CH role and improves the cluster lifetime

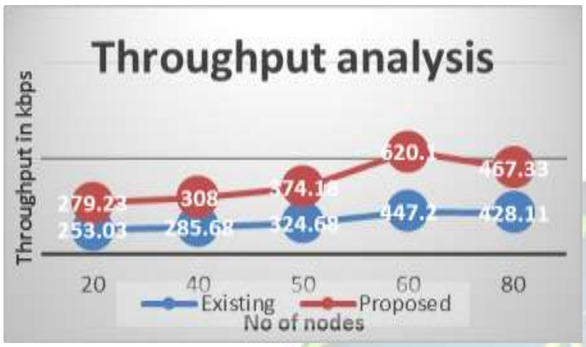

Fig.4.1 Throughput vs No of Nodes

The fig 4.1 shows that the comparison of throughput between existing method and proposed method. This comparison shows that the proposed method throughput is 18% higher than the existing method throughput.

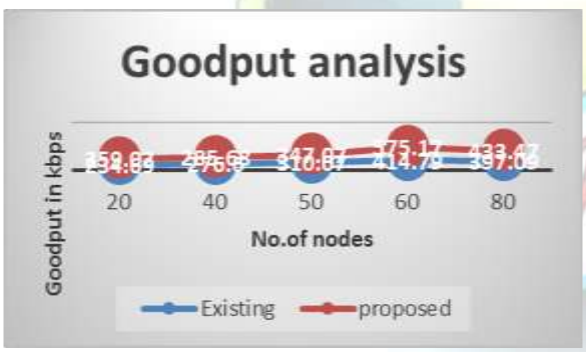

Fig.4.2 Goodput vs No of Nodes

The fig 4.2 shows that the comparison of goodput between existing method and proposed method. This comparison shows that the proposed method goodput is 16% higher than the existing method goodput.

Fig.4.3 End to End Delay vs No of Nodes

The fig 4.3 shows that the comparison of end to end delay between existing method and proposed method. This comparison shows that the proposed method end to end delay is 10% lower than the existing method.

V. CONCLUSION

The proposed method algorithm is implemented and analyzed in wireless sensor networks using NS2 software. From the simulation analysis of proposed window growth mechanism over the existing mechanism, shows that the proposed mechanism is having 18% improvement in the throughput and 16% improvement in the goodput and 10% lower than the existing method and also decrement in packet drop.

In future, this is very much helped for fast communication. The proposed method adopted to wireless sensor networks to improve the performance and increase the network lifetime.

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