ISSN:0975-9646
Meenakshi Dhull et al, / (IJCSIT) International Journal of Computer Science and Information Technologies, Vol. 3 (2) , 2012,3305-3312

Routing Protocols and Energy efficient protocols for Data Aggregation in Wireless Sensor Network: A Survey

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Abstract: A sensor in wireless sensor networks (WSNs) periodically produces data as it monitors its vicinity. The basic operation in such a network is the systematic gathering (with or without in-network aggregation) and transmitting of sensed data to a base station for further processing. A key challenging question in WSNs is to choose best routing protocol to gather data from various sensing devices and send it to the base station (sink). Routing protocols used in various networks (homogeneous, heterogeneous and hybrid) are the same. Routing protocol which consumes less energy and produces minimum traffic is used in that particular network. This paper give a survey of different routing protocol and a way to save energy used for data aggregation in sensor network. . The propose protocol is based on a network which uses HYBRID sensors and it will depend upon the RANGE of sensors to detect the vicinity. The protocol focused on minimizing traffic in the sensor node and energy consumption by sensors. The information will be transmitted as trans-receiver. There are using a two different radio, low power radio is use for detect to the event and high power radio is used for data transmission.

***Keywords*: Wireless sensor network, Hybrid network, sensor node, data aggregation, routing protocols.**

1. INTRODUCTION

Wireless sensor networks consist of sensors deployed over a given area. Sensors monitor physical or various environmental conditions and then cooperatively pass their data to the base station. Wireless sensor networks (WSNs) periodically produce data as it monitors its surroundings. Sensor nodes consisting of multiple sensing device. The collection of different sensor node called as heterogeneous wireless sensor network. In heterogeneous sensing network there are various sensors which sense different parameter or attributes like:- Temperature field unit, Pressure field unit, humidity field unit, Analog input field unit etc The basic operation of wireless sensing network is the systematic gathering and transmitting of sensed data to a base station for further processing. Scheduling of nodes' activities is done in a way that reduces minimum energy consumption.

The development of wireless sensor networks was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring, and so on. Wireless sensor network consists of several sensor nodes. In many applications, sensor nodes are usually powered by battery and keep on working for several months to one year without recharging. Such densely (up to 20 nodes/m^3), with severe problems such as scalability, redundancy and radio channel contention expectation cannot be achieved without scheduling the energy utilization, especially when sensors are deployed[1].

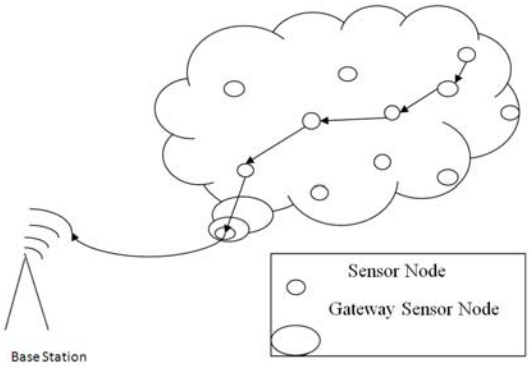

Figure 1 Wireless Sensor Network

Each sensor node consists of sensing unit, processing unit (micro-controller), a transceiver unit and power unit. In wireless sensor network, the resources of sensor node are limited in terms of the processing capability, wireless bandwidth, battery power and storage capacity, which distinguishes wireless sensor network from traditional networks. Various sensor nodes are MICA, TinyOS and so on.

Sensor area the sensing device which monitors the various attributes of the environment. The various attributes includes: humidity, temperature and so on.

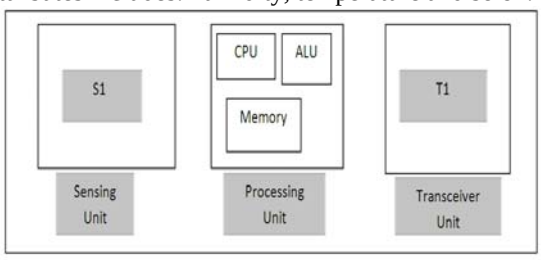

Fig.2 Sensor Node

S1 - Sensing Device,T1 - Transceiver devices,CPU - Central Processing Unit,ALU – Arithmetic Logic Unit

Multi sensor routing protocol: Wireless sensor networks (WSNs) use sensors to monitor phenomena such as temperature, humidity, groundwater levels and transmit this information to a base station using wireless channels. Hybrid sensor networks consisting of both inexpensive static wireless sensors and highly capable mobile robots have the potential to monitor large environments at a low cost. To do so, an algorithm is needed to assign tasks to mobile robots which minimize communication among the static sensors in order to extend the lifetime of the network. A hybrid wireless sensor network includes two networks: an ad hoc wireless network and a wireless sensor network.

2. RELATED WORK:

The main task of data gathering is to forward the sensed data gathered by sensors node to the sink node (base station). Routing protocols for Wireless Sensor Networks (WSNs) are mainly classified into two categories: Network Structure Based protocols and Protocol Operation Based protocols. The network structure based protocols depend on the system architecture of the network. These protocols are classified into three categories: Data centric or flat routing protocols, Hierarchical routing protocols, and Location based routing protocols. Protocol operation based protocols are classified into five categories: Negotiation based routing protocol; Multi-path based routing protocol, Query-based routing protocol, Qos-based routing protocol, and Coherent-based routing protocol [1].

3. VARIOUS ROUTING PROTOCOLS IN WIRELESS SENSOR NETWORK:

A. Data-centric or Flat Routing protocols: In this protocol every node in the network has been assigned the same role i.e. whenever source node requires the data it fires a query in the whole network, then all the sensors nodes provide the information whatever they have related to that query. However this introduces complexity to query data from a specific set of nodes. Therefore the data is collected from the deployed region. Since the collected data is correlated and mostly redundant; collected data is aggregated in some nodes resulting decrease in the amount of transmitted data and so transmission power. The following routing algorithms' main consideration is data and its properties [1].

1. Flooding: The data gathered is broadcasted unless the specified maximum number of hops per packet is reached, or the packet delivered to the destination. This protocol brings implosion, overlap, and resource blindness problems [1].

2. Gossiping: The gathered data is not broadcasted but sent to randomly chosen neighbor node until the specified maximum number of hops per packet is reached or the packet delivered to the destination. The delivery of the data takes so much time [1].

3. SPIN, Sensor Protocol for Information via Negotiation: There are three types of messages: ADV, REQ, and DATA. As shown in Figure 3, the source node broadcast an ADV message to its neighbors, ADV message indeed is meta-data. The interested nodes send REQ, and then the source node sends the DATA to interested nodes. Using same procedure the data can reach interested nodes in the whole network from one end to the other end. Data aggregation is employed [1].

4. Directed Diffusion: The sink broadcasts the "interest" message, namely the task descriptor to all nodes, as shown in Figure 4. The interest is stored to cache of every node, until timestamp of time specified messages expires. The message contains several gradient fields. The gradient to the sink is set up as the interest propagated through network. When the source node gets the interest it sends the data through the gradient path of the interest. The directed diffusion algorithm solves problems of node addressing or maintaining a global network topology, data caching also reduces energy consumption [2].

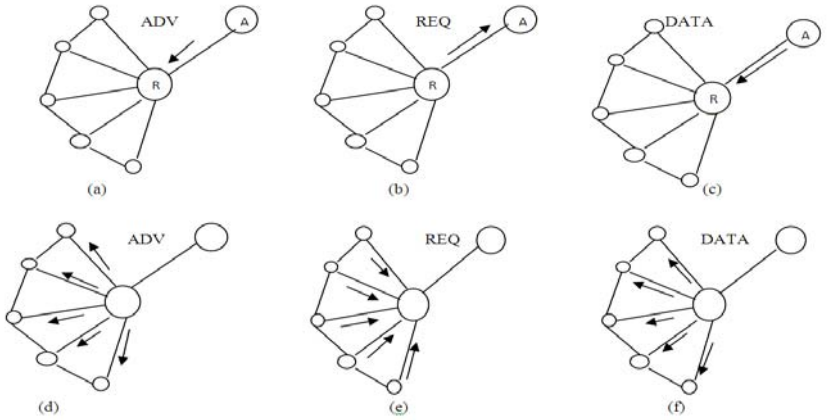

Fig. 3 SPIN protocol

(a) Node A starts by advertising its data to B (b) Node B responds by sending a request to Node A (c) After receiving the requested data, (d) node B then sends out advertisements to its neighbors , (e-f) who in turn sends request back to B

[Research paper "Energy efficient Routing Protocol for Wireless Sensor Network" ming Liu 2007]

5. Energy-aware Routing: In it the paths are chosen according to energy consumption of the path. Use the path that consumes minimum energy frequently deplete energy source of specific nodes. Since one of the certain paths are chosen with equal probability, the network life time increases [3].

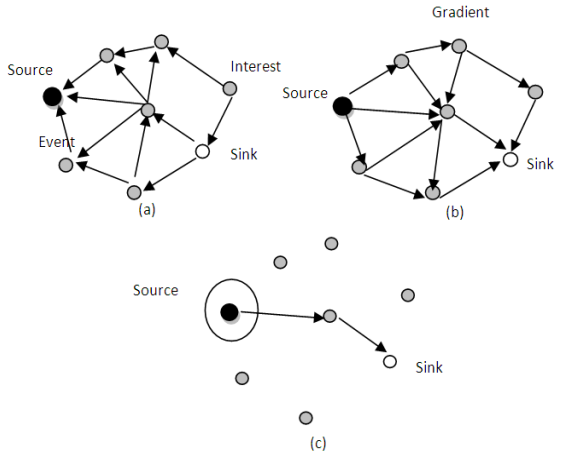

Fig. 4 Directed Diffusion protocol phases. (a) Interest Propagation, (b) Initial Gradient setup and, (c) Data delivery along reinforcement.[Research paper "Energy efficient Routing Protocol for Wireless Sensor Network" ming Liu 2007]

6. Rumor Routing: Rumor routing can be considered as a derivation of "directed diffusion". If the number of queries is large, but number of events is small, directed diffusion becomes inefficient. Considering this shortcoming of the directed diffusion, flooding the events not the queries is proposed. Rumor Routing is another solution to this problem, it is in-between flooding query and flooding event. The main idea is to route the queries to specific nodes that have observed specific events. When a node detects an event, it adds it to its event table and generates an agent in order to flood through network and propagate the detected information to the distant nodes. The sink queries then the query transmitted to the related node easily and efficiently [4].

7. Gradient Based Routing: The interest packet is diffused through network in order to query the data. During the query process, the distance to the sink in terms of number of hops is recorded in the interest packet. Each node can discover the minimum distance from itself to the sink. The gradient is calculated as the difference between the node's gradient and its neighbor's gradient. The node decides to forward the packet to the link with the largest gradient. Three different spreading techniques have been proposed: Stochastic Scheme (when two or more next nodes have the same gradient the node selects one randomly), Energy-Based Scheme (when a node has scarce energy, it increases its gradient), and Stream-Based Scheme (to divert streams away from nodes relaying traffic) [5].

8. CADR, Constrained Anisotropic Diffusion Routing: The objective of the algorithm is to maximize information gain, however this causes a reduction in latency and bandwidth. There are two techniques; CADR and IDSQ (Information-Driven Sensor Querying). In CADR, each node calculates information, cost objective. In IDSQ, querying node determine the node that can provide the most useful information also considering energy cost [6].

9. COUGAR: The network considered as a huge distributed database system. A leader node is selected to aggregate data and transmits the aggregated data to gateway. The gateway is responsible for generating query plan which specifies the necessary information about data flow and in-network computation for incoming query. Then the gateway sends it to the relevant nodes. Query plan also describes how to select a leader [7].

10. ACQUIRE, Active Query forwarding In sensor networks: The algorithm is designed for one-shot, complex queries for replicated data. Although flooding based mechanisms like flooding, gossiping, SPIN, and directed diffusion algorithms are well-suited for continuous, aggregate queries because cost of initial flooding can be compensated and can become negligible during continuous data flow from source(s) to the sink, these algorithm are not energy efficient for one-shot, complex queries for replicated data. The algorithm sees the network as a distributed database. Sending sink the query, each node receiving the query responds using its pre-cached information, and forward it to the other nodes. The pre-cached information is continuously updated. The complex queries are resolved to simple sub queries while the query is forwarded through a path in the network. After resolving the query completely, the information send back to the sink reverse or the shortest path is used. The algorithm is efficient if complex queries are common for the network [8].

B. Hierarchical or Cluster-Based Routing Protocols

Hierarchical routing or cluster based routing protocols have been proposed in order to meet the energy efficiency and scalability requirement of the WSNs. The main issue is forming sub network clusters, encouraging multi hop transmission and enabling data fusion [1].

1. LEACH, Low Energy Adaptive Clustering Hierarchy: LEACH is proposed for the reducing power consumption. In it clustering task is rotated among the nodes, based on duration. Direct communication is used by each cluster head to forward data to the sink node. LEACH is based on technique that combines all the original data into the meaningful information from all

the individuals, so reduce the amount of transmitted data, thus making routing and data dissemination more scalable and robust. LEACH rotates high-energy cluster head, to give a chance to all sensors to act as cluster head, thus avoid battery depletion of an individual sensor and dieing quickly. The operation of LEACH is divided into rounds having two phases namely: (i) a set-up phase (to organise the network into cluster head advertisement and transmission schedule creation) (ii) a steady-state phase (to aggregate, compress and transmit to the sink node). LEACH is completely distributed and requires no global knowledge of network. It reduces energy consumption by (a) minimizing the communication cost between sensors and their cluster heads and (b) turning off non-head nodes as much as possible. Leach uses single-hop routing where each node can transmit directly to the cluster head and sink node. So, it is not used in networks deployed in large area [9].

2. Power-Efficient Gathering in Sensor Information Systems (PEGASIS): PEGASIS is an extension of the LEACH protocol, which forms chains from sensor nodes so that each node transmits and receives from neighbor and only one node is selected from that chain to transmit to the sink node. The data is gathered and moves from node to node and aggregated and then sent to the sink node. Unlike LEACH, PEGASIS avoids cluster formation and uses single node to transmit the data. In PEGASIS, the construction phase assumes that all the sensors have global knowledge about the network. PEGASIS uses greedy approach. When a sensor fails or dies due to low battery power, the chain is constructed using the greedy approach.

Advantages of PEGASIS over LEACH: (i) it reduces the per round energy expenditure. (ii) increases the lifetime of the network twice. PEGASIS requires dynamic topology to know about energy status of its neighbors in order to know where to route its data.

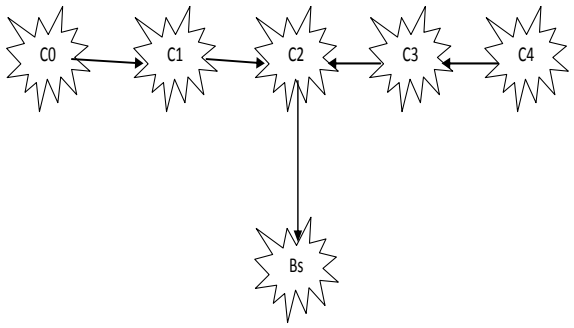

Fig.5 Chaining in PEGASIS

Figure 5 illustrates PEGASIS algorithm. Node c_0 and c_4 forwards the obtained data to c_1 and c_3, respectively. Node c_1 and c_3 aggregates the data and forward it to c_2. Node c_2 is responsible for sending the gathered data to the base station [10].

3. Hierarchical-PEGASIS: The protocol is an extension of PEGASIS aiming to decrease the delay. Simultaneous transmissions are employed. In order to avoid collisions of simultaneous transmissions, two different solutions are proposed: The first possible solution can be employing signal coding namely CDMA; the other is allowing simultaneous transmission only for spatially separated nodes.

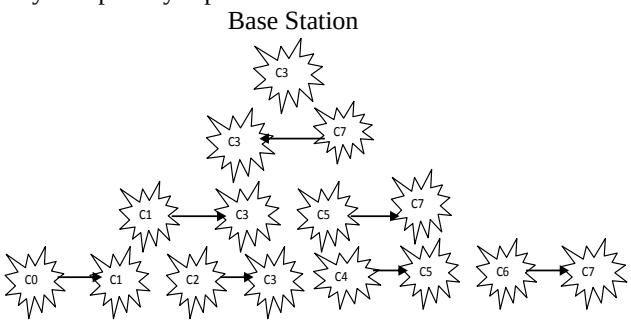

Fig. 6 Hierarchical PEGASIS for chain based

Figure 6 illustrates the algorithm. Nodes c_0, c_2, c_4, and c_6 forward their obtained data to c_1, c_3, c_5, and c_7, respectively. Doing the data aggregation, c_1 and c_5 forwards the data to c_3 and c_7. Then c_7 sends the aggregated data to c_3. Node c_3 is responsible for sending the gathered data to the base station. If PEGASIS is employed for this network it will take 4 unit times to transmit all the data to c_3, whereas it takes 3 unit times. The difference will increase with increasing network size [11].

4. Threshold Sensitive Energy Efficient Sensor Network Protocol (TEEN): TEEN is a hierarchical clustering protocol, which groups sensors into clusters with each led by a cluster head(CH). The sensors within a cluster report their sensed data to their CH. The CH sends aggregated data to higher level CH until the data reaches the sink. Thus, the sensor network architecture in TEEN is based on a hierarchical grouping where closer nodes form clusters and this process goes on the second level until the Base Station (sink) is reached. TEEN is useful for applications where the users can control a trade-off between energy efficiency, data accuracy, and response time dynamically. TEEN uses a data-centric method with hierarchical approach. Important features of TEEN include: (i) its suitability for time critical sensing applications, (ii) the energy consumption in this scheme is less than the proactive networks. However, TEEN is not suitable for sensing applications where periodic reports are needed since the user may not get any data at all if the thresholds are not reached [12].

5. Adaptive Periodic Threshold Sensitive Energy Efficient Sensor Network Protocol (APTEEN): APTEEN is an improvement to TEEN to overcome its shortcomings and aims at both capturing periodic data collections (LEACH) and reacting to time-critical events (TEEN). Thus, APTEEN is a hybrid clustering-based routing protocol that allows the sensor to send

their sensed data periodically and react to any sudden change in the value of the sensed attribute by reporting the corresponding values to their CHs. The architecture of APTEEN is same as in TEEN, which uses the concept hierarchical clustering for energy efficient communication between source sensors and the sink. APTEEN supports three different query types namely (i) historical query, to analyze past data values, (ii) one-time query, to take a snapshot view of the network; and (iii) persistent queries, to monitor an event for a period of time. APTEEN guarantees lower energy dissipation and a larger number of sensors alive [13]**.**

C. Localization routing protocol:

We can divide our location algorithm into two parts based on the measuring system used: GPS based and GPS free localization algorithm [14].

1. GPS based localization Algorithms:- In GPS based localization algorithm we require a GPS system because GPS system is the one way to find the position of the node. In this technique, few nodes commonly known as *anchors*, use GPS to determine their location using GPS system and, broadcast its position's information in the network. This position information has cached by the other node in the network and with the help of this information other nodes (neighbor nodes) in the network calculate their own position without using GPS.

GPS based localization algorithm is divided into two parts, based on the range of the anchor nodes: *Range-free* and *Range-Based.* Monte Carlo localization algorithm ([15],[16]) and color-theory-based dynamic localization algorithm([17]) etc. are the example of range free algorithm. *Range-free algorithms* do not need absolute range information; the accuracy is less than the range-based but satisfies many applications requirements and range free algorithms are cost effective than range based algorithms. Range-based localization algorithms use techniques such as radio signal strength indicator (RSSI)([18],[19]) or radio and ultrasound with angle-ofarrival(AOA)([20],[21]) or time-difference-of arrival (TDOA).

1.1 Sequential Monte Carlo localization Algorithm

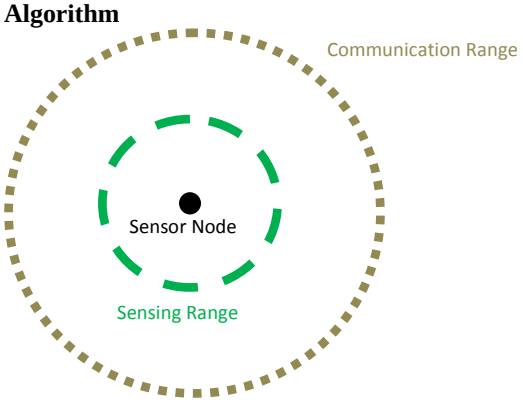

Fig.7 various range of the sensor node[14]

The Monte Carlo localization algorithm is mainly used for the robot localization which is based on its motion, perception, and possible pre-leaned map of its environment. This algorithm is used for mobile sensor node. This is the first range free localization algorithm for mobile sensor network. The Sequential Monte Carlo localization algorithm has three steps: *Initialization step, Prediction step, and filtering step.* Prediction step and filtering step are combined called *location estimation* step.

In the first step (*initialization step*), initially the node has no knowledge about its location.

In the *Prediction steps*, the authors assume that every node aware about its speed and direction

In the *filtering step*, all the impossible locations are removed from the sample [14].

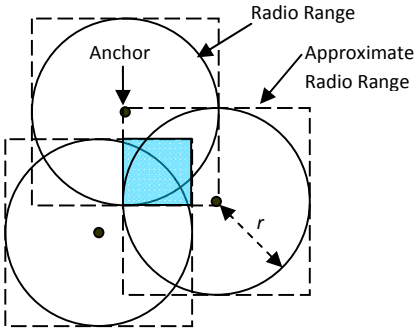

Fig.8 Building Anchor Box[14]

1.2 Monte Carlo localization: As shown in figure 8 example of an anchor box (shaded area) in the case a node hear three one-hop or two hop anchors and draw a box where the radio range of these three anchors are overlaps. This box is termed as *anchor box*. This region is called deployment area where the nodes have to be localized. For each one-hop anchor heard, a node builds a square of size *2r* centred at the anchor position, *r* being the radio range. Since the dimensions of the anchor box is approximately equal to the radio range of the anchor node so it is easy to filter the predicted sample within this region. The prediction and filtering steps are repeated until the required sample is no found. Thus by using the anchor information for the anchor box Aline et. al. improve the efficiency of the localization, and gives the better accuracy, the coverage of the localization also improve [14].

1.3 Color theory based Dynamic Localization algorithm:- The colour theory based localization algorithm is proposed by the Shen-Hai Shee et. al. [22], it comes under the category of Range-free localization algorithm. In this algorithm, a sensor node is represented by the set of RGB value. With the help of RGB value we can find the most possible location of the sensor node. This centralized localization algorithm is based on the colour theory to perform positioning in mobile wireless sensor networks. For localization of the

sensor node the RGB value of the sensor node is frequently updated. It builds a location database in the server, which maps a set of RGB values to a geographic position and measure the distance between sensor nodes that are based on the DV-Hop [23]. The color theory based algorithm uses the two algorithms: RGBtoHSV and HSVtoRGB. The RGBtoHSV algorithm converts the RGB values to HSV values, which is received by a sensor node from its anchor node. Here HSV stands for Hue, Saturation, and Value. Based on color theory, only the lightness of color fades out with the increasing of propagating distances. That is, the V of HSV of an anchor, which is corresponding to the lightness, is decreased in proportion to the distance from the node to the anchor.

$$H_k, S_k, V_k = RGBtoHSV(R_k, G_k, B_k)$$

$$H_{ik} = H_k, \quad S_{ik} = S_k, \; V_{ik} = V_k * (1 - D_{ik} / Range)$$

$$Ri_k, Gi_k, Bi_k = HSVtoRGB(Hi_k, Si_k, V_{ik})$$

$$R_i, Gi, Bi = (1/n) * \sum_{k=1}^{n} (Ri_k, Gi_k, Bi_k)$$

And by using HSVtoRGB algorithm the new HSV value is converted back to RGB value. The node then calculates its own RGB values by averaging these adjusted RGB values, corresponding to the anchors. The node then sends its RGB values to the server so that the server can find its most probable location by looking up the location database. The RGB value first randomly assign to the anchor node from 0 to 1. After a sensor node *i* obtain the each anchor RGB value and the hop count and convert it into HSV value by using the RBGtoHSV algorithm. With the help of hop count and hop distance from the anchor node the HSV value is updated and this HSV value is converted back to RGB value. The RGB value of the node *i* is the mean of the RGB value obtain from the *n* anchor nodes as shown in figure 9 . The above equations are used in the whole process.

A location database is established when the server obtains the RGB values and locations of all anchors. The mechanism is based on the theorem of the mixture of different colors. With the RGB values of all anchors, the RGB values of all locations can be computed by exploiting the ideas of color propagation and the mixture of different colors. The location for each sensor node can be constructed in the location database by maintaining the coordinate (x_i,y_i) and the RGB values (R_i,G_i,B_i) at each location *i*. Then, the location of a sensor node can be acquired by looking up the location database based on the derived RGB values [14].

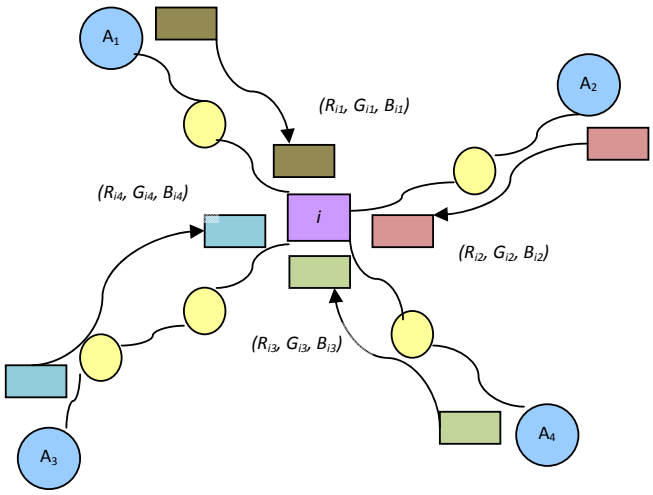

Fig.9 Node *i* obtain the RGB value from different anchors [14]

2. GPS free localization Algorithms:-

GPS Based localization algorithm requires some GPS system which only suitable for outdoor environment and has several disadvantages:

- the availability of GPS signals,
- the availability of global positioning systems (GPS) which requires additional hardware at additional costs,
- size of the sensor nodes,
- power of the sensor nodes and
- the availability of a number of fixed-point reference nodes, or anchors, with globally known locations. Due to these reason we require an algorithm which is GPS free [14].

4. PROPOSED WORK

Wireless sensor networks (WSNs) use sensors to monitor phenomena such as temperature, humidity, groundwater levels and transmit this information to a base station using wireless channels. Hybrid sensor networks consisting of both in-expensive static wireless sensors and highly capable mobile robots have the potential to monitor large environments at a low cost. To do so, an algorithm is needed to assign tasks to mobile robots which minimize communication among the static sensors in order to extend the lifetime of the network. A hybrid wireless sensor network includes two networks: an ad hoc wireless network and a wireless sensor network. Hybrid sensors networks differ from hybrid ad-hoc network in that the communication scenario in a, hybrid sensor network is many-to-one, rather than the many-to-many communication scenario, which is typical of hybrid ad hoc networks. Topology control in a sensor network balances load on sensor nodes and increases network scalability and lifetime. Clustering sensor nodes is an effective topology control

approach. A novel distributed clustering approach for long-lived ad hoc sensor networks does not make any assumptions about the presence of infrastructure or about node capabilities, other than the availability of multiple power levels in sensor nodes. In a protocol, HEED (Hybrid Energy-Efficient Distributed clustering), that periodically selects cluster heads according to a hybrid of the node residual energy and a secondary parameter, such as node proximity to its neighbors or node degree.

1 Node architecture: The proposed work involve multi-sensor which have many sensing units in a single sensor node. The various sensing devices sense different field units like: temperature field unit, pressure field unit, humidity field unit etc. In multi-sensor node we lower energy consumption of sensing unit. Also only relevant data is send to the base station. The Sensor devices sense various field units at the same time. The data is being processed by the processing unit like CPU (Central Processing unit), ALU (Arithmetic field unit) and memory. The transceiver is used to send and receive the data from the sensing unit. The transceiver used in sensing unit is radio.

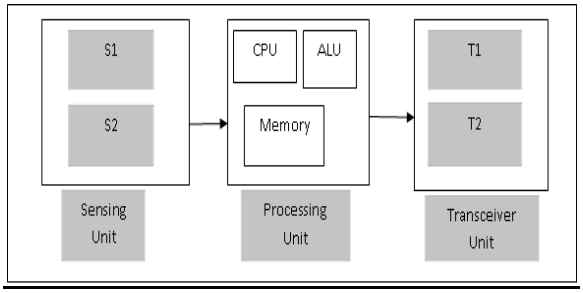

Fig.10 Multi-sensing node

S1, S2- Sensing devices
T1, T2- Radios
CPU- Central Processing Unit
ALU- Arithmetic Logic Unit
T1- low power signal-> detect event
T2- high power signal-> send the data to base station
S1, S2- sensing nodes

2. Proposed algorithm

Algorithm :-

Consider two sensing devices S1 and S2. Sensing device S1 denotes temperature and S2 denotes humidity. The processing of data is done by processing unit. The various processing unit includes Central Processing unit, Arithmetic Logical Unit and memory. The transceiver unit is used for sending and receiving the data to and from the base station respectively. Data=0 when data is being sensed by sensing device S1 means at this time sensing device S2 is in sleep mode.

Node Scheduler

1 Sensing devices S1, S2.

2 Sense the data; ($data_{S1}$ and $data_{s2}$) through T1; E(event)

3 if (T1=E)

If (data=0) then

Sensor S1 detect the data and send through T2; Data S1

S2-sleep mode

4 Else

Sensor S1 = sleep mode

S2 = wake up mode

S2 transmit the $data_{S2}$ through T2

5 else T2 = sleep mode.

Working:

2.1 event sensing: We consider two sensing devices S1, S2 in a sensor node. When sensing device S1 detects any event in its vicinity then it wakes up and sends the accurate data to the base station via high power consumption. When S1 is in wake mode then sensing device S2 is in sleep mode. When sensing device S1 detects no change in its vicinity then it goes to sleep mode and then S2 wakes up and senses the neighbors. No two sensing devices can be in same mode at the same time.

Data Flag bit

Flag bit = 0, temperature

= 1, humidity

2.2 Data transmission: Initially sensor S1 is in wake mode and detect if there is any change in its vicinity. At that time S2 is in sleep mode.

S1 awake
S2 sleep

When S1 detects changes it goes to sleep mode and S2 awakes and observe its neighbor, if there occurs any change.

S1 sleep

S2 awake

5.CONCLUSION

Wireless sensor networks (WSNs) periodically produces data as it monitors its surroundings. Sensor nodes consisting of multiple sensing devices. The collection of different sensor node called as heterogeneous wireless sensor network. In heterogeneous sensing network there are various sensors which sense different parameter or attributes like:-Temperature field unit, Pressure field unit, humidity field unit, Analog input field unit etc. The propose protocol is based on a network which uses HYBRID sensors and it will depend upon the RANGE of sensors to detect the vicinity. The protocol focused on minimizing traffic in the sensor node and energy consumption by sensors. The information will be transmitted as trans-receiver. There are using a two different radio, low power radio is use for detect to the event and high power radio is used for data transmission. The basic operation of wireless sensing network is the systematic gathering and transmitting of

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