HETEROGENEITY IN DISTRIBUTED WIRELESS SENSOR NETWORKS

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Abstract : Wireless Sensor Networks comprises of a number of nodes equipped with sensors, made for applications which sense data from distant locations where wired connections are not feasible. Heterogeneous nodes, in contrast to homogeneous nodes, comprised of nodes with distinctive capabilities like diverse computing power and sensing range. Heterogeneous wireless sensor networks are more likely to exist in real life. Also, certain circumstanced causes homogeneous network to convert into heterogeneous network. Therefore, researchers consider heterogeneity in networks while developing energy efficient clustering technique. Various levels of heterogeneity can occur in a network. In this paper, discussions have been made on two level, three level and multilevel heterogeneous wireless sensor networks. The heterogeneity model affects the number of nodes of a particular type based on their initial energies. More efficiency is achieved as levels of heterogeneity increased.

Index Terms **- Wireless Sensor Network, Heterogeneous WSN Model, Clustering, Energy Consumption.**

I. INTRODUCTION

Wireless Sensor Network consists of spatially distributed autonomous devices using sensors where all nodes sense data and send it to base station which is usually called sink. Due to huge range of applications like military, critical infrastructure protection, healthcare, etc. recent scientific developments have been done on wireless sensor network (Akyildiz et al. 2002). Also, to exchange or restore the batteries of deployed nodes is not realistic as many applications require energy efficient networks. Routing protocols are useful to achieve energy efficiency in WSNs. In order to minimize energy consumption, clustering is used where group of nodes in a cluster select a clusterhead and send data to clusterhead. Clusterhead further send the data to base station by aggregating the data from various nodes (Pottie and Kaiser 2000).

II. FEATURES OF WSN

The various features of WSNs as per contrast to traditional wireless sensor networks are:

2.1Dynamic Network Topology

Dynamic network topology is the prime feature of WSN. In this, the nodes can be added or removed in the network because the topology of dynamic network topology changes as required due to which sensing node disappointments, channel fading or energy reduction occurs.

2.2Application Specific

As per the application essentials, the design requirements for the system may differ (Garg 2017).

2.3Power constrained

As the nodes are portable in nature and have limited energy, storage and computation capacities, therefore sensing element is required to be power constrained.

2.4Self-configured

In self-configurable environment, the nodes are first randomly deployed and then corresponding to an arrangement, they need to configure themselves autonomously. Without any assistance, the nodes randomly arrange in such environment (Potdar, Sharif, and Chang 2009).

III. WSN ROUTING PROTOCOLS

Some routing algorithms have been developed to optimize the energy utilization. These algorithms are certain set of rules that describes how from source to sink message transfer takes place with lesser power utilization in WSNs.

3.1Course Establishment

1) Pro-Active or Table Driven Routing Protocols

In this routing, using traditional routing approaches, the protocols register all the routes. For Example: In DSDV, distance vector is used to store the routes in routing table for every node. Any changes in the routes are updated periodically. But pro-active routing protocols are not good for WSNs because due to number of nodes present in WSN and to refresh those nodes it needs to keep tremendous charge.

2) Reactive or on-demand Routing Protocols

This protocol uses broadcast route question or direction request messages in the system to get the route from source to sink. It determines the route only when it is required.

3) Hybrid Protocols

The combination of Proactive and reactive protocols are called hybrid protocols.

B. Network Structured Protocols

1) Flat-based Routing Protocols

There is an association of every sensing element while executing a detection job and at a same level there is an equivalent role of each node.

2) Hierarchical-based Routing Protocol

In this type of routing, the sensing elements are arranged into groups. A group has two types of elements, one is Clusterhead which have better energy that other elements and the other type is Cluster Members which have lower energy than Clusterhead. Clusterhead will use its energy to gather information from other members of cluster and cluster aggregate the data collected from various nodes and send that to the sink node. This Protocol improves the system scalability, system dependability and system lifetime.

3) Location-based Routing Protocol

In such routing procedures, the communication between sensing elements is based on the position of one sensing node with other node. There are 2 routes to measure the separation or position. Both can be figured out by incoming signal quality from supply or with the use of GPS (Global Positioning System).

C. Protocol Operation

1) Multipath-based Routing

Instead of using single path, on the cost of expanding power utilization and overhead of directing periodic messages to alternative routes, there is a way to use multiple paths to expand adaptation to internal failure of system along with a goal to keep them alive, known as multipath-based routing.

2) Query-based routing

In this routing, for sending information, the destination sensing element broadcast a question/query to the network. Only that sensing element can send information to desired node that matches with the query/questions of information. Usually a consistent language based queries are used for sending the information.

3) Negotiation-based routing

A system between power utilization and information value has been settled by QoS with a specific end destination to fulfill some QoS (Quality of Service) metrics delay, bandwidth, and capacity. The network application business and its functionalities prompt the need for ensuring a QoS (Quality of Service) in the data exchange. In particular, effective sample rate, delay bounded and temporary precision are often required. Satisfying them is not possible for all the routing protocols as the demands may be opposite to the protocol principles. For instance, a routing protocol could be designed to extend the network lifetime while an application may demand an effective sample rate which forces periodic transmissions and, in turn, periodic energy consumptions.

4) QoS-based Routing

A system between power utilization and information value has been settled by QoS with a specific end destination to fulfill some QoS (Quality of Service) metrics delay, bandwidth and capacity.

5) Coherent-based Routing

In this routing protocol, the constrained preparing of information is either in light of or done by minimum processing (intelligible) or by full handling (non-coherent).

IV. Energy Consumption In WSNs

Consider a sensor network model, consists of one base station, also known as a sink, and a large number of sensor nodes deployed over a large geographic field. Data transmission takes place from sensor nodes to sink node. The lifetime of WSNs is influenced by the energy consumption of sensor nodes in the network.

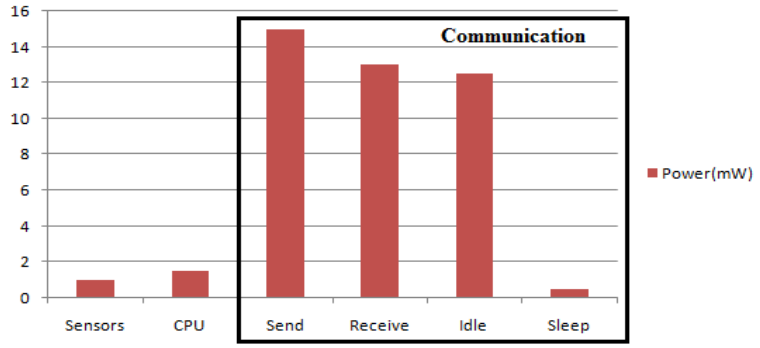

Figure. 3.1 Energy Consumption of a Sensor Node (Yan, Zhou, and Ding 2016)

As the Fig. 3.1 depicts, the energy consumed during the communication phase of a typical sensor node is more than other phases. In a typical sensor node, the energy consumed while transmitting a single bit of information is approximately equal to the energy needed for processing thousands of operations (Pottie and Kaiser 2000). The wireless communication module has further four states: send, receive, idle and sleep. Amongst these four, send and receive i.e. transmitting signals take 2/3 of the total energy consumption by the communication module. But the number of data packet transmission depends on the routing strategy. Therefore, to balance the energy consumption levels among WSN nodes, an efficient routing protocol should be used. This can improve the quality of data transmission during network lifetime. As the energy consumption is minimal at sleep and idle states, researchers often consider the energy consumption of sending and receiving states only.

V. Heterogeneity in Wireless Sensor Networks

For real life applications, it is more likely to have a wireless sensor network having nodes with varying initial energy. If a network is created with homogeneous nodes, even then its nodes will end up having different energies after some transmissions. This happens because the energy dissipation of each cluster member is different as its distance from the clusterhead is different.

The energy dissipation for cluster member involves only energy required to transmit data. On the other hand, the energy dissipation for clusterhead involves transmission energy and also energy required to receive the data from its cluster members. So, the energy dissipation will be different clusterheads and also for cluster members. Thus, it results in varying energies of different nodes (Smaragdakis, Matta, and Bestavros 2004).

There can be another scenario where suppose energy of all the nodes comes nearby to a threshold value. At that point, some additional energy is provided to all the nodes. But that amount is same for every node. Therefore, in such case also, there occurs heterogeneity in network.

Heterogeneity is the main reason why most of the researchers focused on this factor and consider heterogeneity while choosing clusterheads. In such researches, after every round, the remaining energy of each node is evaluated and considered. Further, based on this, clusterheads are decided (Javaid et al. 2015).

VI. Heterogeneous WSN Model

With respect to their energy levels, heterogeneous WSNs include two, three or multi types of nodes and are known as two, three and multilevel heterogeneous WSNs respectively.

A. Two Level Heterogeneous WSN

There are two energy levels of nodes in two level heterogeneous WSNs termed as normal and advanced nodes. The normal node is associated with energy level $E_o$and advanced nodes containing a times more energy as compared to normal nodes which is$E_o(1 + a)$. For total a number of nodes to be N, there are $N.m$ number of advanced nodes where m refers to the fraction of advanced nodes and $N(1 - m)$ is the number of normal nodes. The sum of energies of normal and advanced nodes gives the total initial energy of the network:

$$N_{adv} = N.m \tag{1}$$

$$N_{nrm} = N.(1 - m) \tag{2}$$

The initial energy associated with a total number of advanced and normal nodes is given as:

$$E_{adv} = N.m.(1 + a).E_o \tag{3}$$

$$E_{nrm} = N.(1 - m).E_o \tag{4}$$

The total initial energy of the network is the sum of energies of normal and advanced nodes:

$$E_{total} = N.(1 - m).E_o + m.N.(1 + a).E_o$$

$$= N.E_o.(1 - m + m + am)$$

$$= N.E_o.(1 + am) \tag{5}$$

The two level heterogeneous WSNs contain am times more energy as compared to homogeneous WSNs (Qing, Zhu, and Wang 2006).

B. Three Level Heterogeneous WSN

Three different energy levels of nodes are contained in three level heterogeneous WSNs called as normal, advanced and super nodes. Normal nodes are associated with energy of E_o, advanced nodes of fraction m are having a factor of a times more energy than normal nodes so their energy is equal to $E_o(1 + a)$ whereas, the super nodes of fraction m_o are having b times extra energy than normal nodes equal to $E_o(1 + b)$ (Kumar, Aseri, and Patel 2009). The total number of normal, advanced and super nodes in network are therefore given by:

$$N_{nrm} = N.(1 - m) \tag{6}$$

$$N_{adv} = N.m.(1 - m_o) \tag{7}$$

$$N_{sup} = N.m.m_o \tag{8}$$

The initial energy associated with a total number of super, advanced and normal nodes is given as:

$$E_{adv} = N.m.(1 - m_o).(1 + a).E_o \tag{9}$$

$$E_{nrm} = N.(1 - m).E_o \tag{10}$$

$$E_{sup} = N.m.m_o.(1 + b).E_o \tag{11}$$

The total initial energy of three level heterogeneous WSN is therefore given by:

$$E_{total} = N.(1 - m).E_o + m.N.(1 - m_o).(1 + a).E_o + m.N.m_o.(1 + b).E_o$$

$$= N.E_o.(1 + m.(a + m_o.b)) \tag{12}$$

The three level heterogeneous WSNs contain $m.(a + m_o b)$ times more energy as compared to homogeneous WSNs (Kumar, Aseri, and Patel 2009).

C. Multi-level Heterogeneous WSN

Multi-level heterogeneous WSN is a network that contains nodes of multiple energy levels. In multi-level heterogeneous networks, initial energy of sensor nodes is randomly distributed over the close set $[E_o, E_o(1 + a_{max})]$, where E_o is the lower bound

and a_{max} determine the value of the maximal energy. Initially, the node s_i is equipped with initial energy of $E_o.(1+a_i)$, which is a_i times more energy than the lower bound E_o. The total initial energy of the multi-level heterogeneous networks is given by [7]:

$$E_{total} = \sum_{i=1}^{N} E_o(1+a_i)$$
$$= E_o\left(N + \sum_{i=1}^{N} a_i\right) \quad (13)$$

Most of the recent researches have been made considering the WSN model to be two level or three level heterogeneous WSN. CH nodes consume more energy as compared to member nodes so after some rounds energy level of all the nodes becomes different as compared to each other. Therefore, heterogeneity is introduced in homogeneous WSNs and the networks that contain heterogeneity are more important than homogeneous networks (Qing, Zhu, and Wang 2006).

VII. Conclusion

Earlier various routing protocols were considered for the efficient energy consumption in WSNs. In this paper, we observed various other factors that may affect the consumption of energy in a wireless sensor network. It has been observed that most of the energy is consumed while transmitting and receiving data. So, due to this reason, researchers are more concerned about developing a protocol that consider these factors. Earlier, researchers consider the network to be homogeneous. But, it has been observed that there are various situations when there exist heterogeneous network. By considering heterogeneity, three levels of heterogeneity has been discussed in this study and observed that increase in level of heterogeneity leads to more efficient networks.

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