A survey – Energy Efficient Routing protocol for Homogenous & Heterogeneous Networks

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Abstract: The wireless sensor networks have gained a lot of grasp in the previous years due to various encroachments in this field. One of the major challenges faced by WSNs is the problem of energy efficiency. Various routing protocols have been used for improving the lifetime of WSNs. In this paper, we have discussed various protocols for homogeneous as well as heterogeneous sensor networks. For homogeneous networks, LEACH, LEACH-C and PEGASIS protocols are used. For heterogeneous networks, EDDEEC and BEENISH protocols are used. Theoretical analysis shows that heterogeneous protocols results in better throughput, stability and improved lifetime of network.

Keywords: Wireless sensor networks, heterogeneous, homogeneous, CH, network lifetime.

I. INTRODUCTION

Wireless sensor network is a geographical area in which a large number of sensor nodes are deployed to sense the events. These sensor nodes are small in size but are equipped with embedded microprocessors, radio receivers and power components to enable sensing, computing, communication and actuation. These nodes are distributed over large area to monitor various physical or environmental conditions such as humidity, pressure, temperature etc. The wireless sensor network mainly comprises of a sensor nodes and a base station. The sensor nodes are in hundreds or thousands, which sense the information and transmit the sensed data to the base station.

According to the energy level of the sensor nodes the wireless sensor networks falls into two categories: 

Homogeneous: In these networks, all the sensor nodes in a wireless sensor network have same energy level. All the nodes have same functionality and hardware complexity. These networks perform well in short range transmission.

Heterogeneous: In these networks, all the sensor nodes in a wireless sensor networks have same or different energy level. These networks are best suited for long range transmission. The lifetime of the network can be improved by using heterogeneous networks because these comprise of nodes having varying energy levels.

Figure 1: Architecture of WSN

As shown in figure 1, the sensor nodes are partially distributed in the sensor field. These sensor nodes sense the data and send it to the sink and end users. Data are routed back to the end users by multihop infrastructure less architectures through the sink. The sink may communicate with task manager through internet or satellite [1].

Wireless sensor networks are gaining attraction in almost every field because of huge advancements being done on it from the past few decades. The wireless sensor networks finds applications in environmental monitoring, military surveillance, health monitoring systems, traffic
control, disaster prediction, manufacturing, transportation and many more. Since the sensor nodes are low power devices, energy consumption is one of the major challenges faced by wireless sensor networks. Various routing protocols have been used to make the sensor networks energy efficient by reducing the energy consumption of each node and thus increasing the lifetime of the network. This paper deals with the study of various routing protocols which have been used for making the system energy efficient in recent years.

II. RELATED WORK

The main aim of using routing protocols is to maintain the energy efficiency of sensor networks by minimizing the power consumption of WSNs. For homogeneous WSNs, [1] [2] [3] [4] discussed a hierarchical routing protocol known LEACH (Low Energy Adaptive Clustering Hierarchical) protocol, in which the sensor network is divided into a group of clusters. The cluster heads are randomly selected and the operation is conducted in rounds. An extension of LEACH, called LEACH-C which uses a centralized clustering algorithm and uses a steady state as that of LEACH [6].

PEGASIS (Power Efficient Gathering in Sensor Information System) is a chain based protocol in which a leader node is used to transmit the information to the base station. The formation of chain is done using a greedy algorithm and the data is transmitted using a token passing approach [4]. For heterogeneous networks, a protocol known as EDDEEC (Enhanced Developed Distributed Energy Efficient Clustering) was proposed by [9]. This protocol uses three nodes of different energy level namely normal, advance and super advance nodes. This protocol distributes the energy evenly between the sensor nodes to make it energy efficient. The nodes with higher energy levels are given more number of chances to become CHs as compared to normal nodes.

Another protocol used for heterogeneous networks is BEENISH (balanced energy efficient network integrated super heterogeneous) protocol [10]. This is an extension of EDDEEC protocol. In this protocol, four levels of nodes are used as compared to EDDEEC, which uses three levels of nodes. The nodes are normal, advance, super advance and ultra advance nodes. The CHs are selected on the basis of residual energy and the average energy of the sensor network. The nodes which fall under ultra advance category have the most number of chances to be selected as CHs. The BEENISH protocol gives the best results in terms of energy efficiency and lifetime of network.

III. PROTOCOLS FOR HOMOGENEOUS NETWORKS

A. LEACH: Low Energy Adaptive Clustering Protocol is one of the most famous hierarchical routing protocols used for energy efficiency in wireless sensor networks. The purpose of LEACH is to randomly select sensor nodes as cluster-heads, as shown in figure 2, so the high energy dissipation in communicating with the base station is spread to all sensor nodes in the sensor network [1].

Figure 2: Cluster formation in WSNs

The operation of LEACH is divided into rounds. Each round consists of a set up phase and a steady state phase. In order to reduce the overhead, the duration of steady state phase is longer than the set-up phase. In set up phase, the cluster is formed and the CH (CH) is selected randomly. The remaining nodes serve as member nodes to sense the information. In steady state phase, the sensor nodes form a TDMA schedule and transmit it to the member nodes. The member nodes sense the information and forward it to the CH in the time slot being assigned to it. On receiving the data from the member nodes, the CH performs the task of data aggregation and then transmits the information to the base station.

On completion of each round, the energy level of each sensor node is checked. If the energy level falls below a particular threshold value, then the sensor node cannot participate in future transmission. The threshold value is calculated as follows:

$$\text{Threshold} = \frac{E_{\text{initial}}}{2}$$

where $$E_{\text{initial}}$$ is the initial energy of the node.

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B. LEACH-C: This is an extension over the LEACH protocol. This uses a centralized clustering approach and the same steady state phase as used in LEACH. In LEACH-C, the CH is selected by the base station. The sensor nodes send its location address and the present state energy level to the base station. The base station establishes the clusters, CH nodes and non-CH nodes in the WSNs. The base station exploits its inclusive information of the network to produce enhanced clusters that require less energy for data transmission. The number of CHs in each round of LEACH-C equals a predetermined optimal value, whereas for LEACH the number of CHs varies from round due to the lack of global coordination among nodes [6].

C. PEGASIS: Power Efficient Gathering in Sensor Information System is another routing protocol which is used for recuperating the lifetime of sensor network. In PEGASIS, the nodes are systematized into chains and each sensor node can transmit and receive information from its neighbour node only. A leader node is selected from the chain, which will transmit the information to the base station. The chain formation is achieved through a greedy algorithm. In this protocol, data aggregation is performed at each node thus reducing per round seepage of the energy as compared to the LEACH protocol. The node, after receiving the information from its neighbour node, aggregates its information with the received data and thus, forwards the aggregated data to its neighbour node. The token passing approach is used by the leader node to initiate the transmission of data from the end nodes.

\[
T(n) = \begin{cases} P & \text{if } n \in G \\ 1 - P & \left[ r \mod \left( \frac{1}{P} \right) \right] \\ 0 & \text{otherwise} \end{cases}
\]

where P is the percentage to become CH, r is the present round and G is the set of nodes that have not being selected as CH in the last 1/P rounds.

LEACH protocol uses the free space as well as the multipath fading radio dissipation models. To transmit a K-bit message over a distance ‘d’, the radio expands as follows:

\[
E_{RS} = \begin{cases} K \cdot E_{elec} + K \cdot e_f \cdot d^2, & d < d_{ov} \\ K \cdot E_{elec} + K \cdot e_f \cdot d^4, & d \geq d_{ov} \end{cases}
\]

And to receive the message, the radio expands as follows:

\[
E_{Rx} = K \cdot E_{elec}
\]

where \( E_{elec} \) is the energy consumed by the device for transmitting one bit of data. \( d_{ov} \) is the cross-over distance, \( e_f \) and \( e_r \) are amplifier energy to the receiver, depending upon the distance and acceptable bit-error. If the distance is less than \( d_{ov} \), the free space model is used (\( d^2 \) power loss); otherwise multipath model is used (\( d^4 \) power loss).

Although LEACH protocol results in energy efficient sensor network but it suffers from some major drawbacks such as the CH selection is random, the CHs are not uniformly distributed in the network and it does not provides good coverage [5].

IV. PROTOCOLS FOR HETEROGENEOUS NETWORKS

A. EDDEEC: The above mentioned protocols are intended for homogeneous networks. These protocols perform meagre in case of heterogeneous networks. Since in heterogeneous networks, all nodes are deployed with different energy levels in their initial stage, these networks maximizes the lifetime of network. The EDDEEC (Enhanced Developed Distributed Energy Efficient Clustering) protocol is mainly designed for heterogeneous networks. The whole operation is performed in rounds. On initialization of each round, the CH is selected based on the level of threshold value as follows:

\[
T(n) = \begin{cases} P & \text{if } n \in G \\ 1 - P & \left[ r \mod \left( \frac{1}{P} \right) \right] \\ 0 & \text{otherwise} \end{cases}
\]
In EDDEEC protocol, the concept of three level of heterogeneity has been used and the nodes are classified as normal, advance and super advance nodes. The probability for CH selection in these nodes is as follows:

$$ P_i = \begin{cases} 
\frac{P_{opt}E_i(r)}{[1 + m(a + m_s(b + u))]} & E(r) \\
\frac{P_{opt}(1 + a)E_i(r)}{[1 + m(a + m_s(b + u))]} & E(r) \\
\frac{P_{opt}(1 + b)E_i(r)}{[1 + m(a + m_s(b + u))]} & E(r) \\
\frac{P_{opt}(1 + u)E_i(r)}{[1 + m(a + m_s(b + u))]} & E(r) 
\end{cases} $$

These are three probability functions for normal, advance and super advance nodes respectively. In case the energy level of normal node dies out, the remaining nodes can continue the functioning of the wireless sensor network resulting in improved stability, lifetime and energy efficiency.

**B. BEENISH:** The balanced energy efficient network integrated super heterogeneous protocol is an extension over the EDDEEC protocol. In BEENISH protocol, four different levels of nodes are used namely normal, advance, super advance and ultra advance. The selection of CH is performed on the basis of average energy of the sensor network. The average energy of the WSN is calculated as follows:

$$ E(r) = \frac{1}{N} E_{total} \left( 1 - \frac{r}{R} \right) $$

where R is the total number of rounds from the starting till the end when all nodes inside a network dies out. It is given as

$$ R = \frac{E_{total}}{E_{round}} $$

$E_{total}$ is the total energy of the network and $E_{round}$ is the energy of one single round in WSN. The probability function for these nodes is determined as follows:

$$ P_i = \begin{cases} 
\frac{P_{opt}E_i(r)}{[1 + m(a + m_s(-a + b + m_1(-b + u)))]} & E(r) \\
\frac{P_{opt}(1 + a)E_i(r)}{[1 + m(a + m_s(-a + b + m_1(-b + u)))]} & E(r) \\
\frac{P_{opt}(1 + b)E_i(r)}{[1 + m(a + m_s(-a + b + m_1(-b + u)))]} & E(r) \\
\frac{P_{opt}(1 + u)E_i(r)}{[1 + m(a + m_s(-a + b + m_1(-b + u)))]} & E(r) 
\end{cases} $$

The value of $P_i$ is calculated for normal, advance, super advance and ultra advance nodes respectively and the value is used in the threshold equation for the selection of CH. Most of the time the ultra advance nodes participate in CH formation because of the highest energy level. This protocol is the most efficient protocol as compared to the previous protocols, in terms of stability, throughput and network lifetime.

**V. CONCLUSION**

This paper presents the role of various routing protocols for homogeneous and heterogeneous WSNs. For homogeneous WSNs LEACH, LEACH-C and PEGASIS protocols have been discussed. For heterogeneous WSNs EDDEEC and BEENISH protocols have been studied. The main idea of using routing protocols is to improve the lifetime of network by minimizing the energy consumption of sensor nodes. BEENISH protocol proved out to be the best among the above discussed protocols as it uses the concept of four levels of sensor nodes which maximizes the lifetime of the WSNs.

**REFERENCES**


