Energy Efficient Routing Protocol for Sensor Networks: A Review

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***Abstract*—**Wireless distributed sensor systems will enable the reliable monitoring of a variety of environments for both civil and military applications. In the proposed paper, we have focused on communication protocols, which have significant impact on the overall energy dissipation of the sensor networks. If the energy consumption is reduced it can prolongs the lifetime of these network. During recent years many energy efficient routing protocols have been developed for Sensor Networks. This paper describes two protocols for distributed clustering and multi-hop routing. We survey different clustering and routing protocols for the sensor network. We have studied their objectives and characteristics and also seen some advantages and disadvantages. Comparison of certain routing protocols based on different parameters is done.

***Keywords*—** *Wireless Sensor Network, clustering protocols, routing protocol*.

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I. INTRODUCTION

Sensor Networks has emerged as an important area for research and development. It has high on daily life it has been used for monitoring of environment, agriculture, habitat, health care, automobiles, disaster prone zones, defense applications and probing of planets. The main task of a wireless sensor node is to sense the data and collect it from a particular area, process them and transmit it to the base station where its application lies [1]. Moreover the sensor network can be used for monitoring as well as controlling. A Sensor Network is one of the major technologies that can be used for real-time monitoring. Sensor Network has the capability of large scale deployment, low maintain, scalability, adaptability for different scenarios [2]. Sensor Network has some limitation such as low memory, power, bandwidth etc. Our aim is to better understand the current clustering and routing protocols for sensor networks and point out the issues that can be subject for further research [3].

This paper is organized as follows. In the first section we have briefly explained the wireless sensor network. We set our work apart from prior surveys on sensor networks. In section 2 we have surveyed the architecture of sensor network. We have seen different clustering and routing protocols. In the next section comparing of all the surveyed protocols is done. Finally in last section we have concluded the paper by summarizing the studied approaches and discussed the scope for future research.

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II. LITERATURE REVIEW

A. Designing of Sensor Network Architecture and Their Issues

Sensor network have various applications, depending upon that different architecture and design goals have been considered for sensor networks. The performance of the routing protocol depends upon the architectural model [3]. The main components for the sensor network are: sensor node, cluster head and base station.

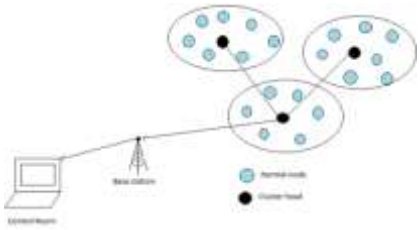

Figure: 1. Basic architecture of sensor network.

1)Designing Issues:

The performance of the protocol depends upon the network architecture. Here we will see some designing issue of network architecture.

a) Network Dynamics: The sensor architecture for various applications may be different. So the network must be of dynamic nature. Most of the network architectures assume that sensor nodes are stationary. But supporting the mobility of sensor nodes and cluster-heads is sometimes necessary [5]. For moving nodes routing of messages from one to other node is more difficult since route stability becomes an important factor, along with energy, bandwidth etc. Depending upon the application the sensing event can either be dynamic or static [6]. The events such as detection and tracking application, is dynamic whereas the event such as monitoring and weather forecasting is static events.

b) Node Deployment: The deployment of the nodes is the important factor of the sensor nodes, this affects the performance of the routing protocol. The deployment of the nodes can be either deterministic or random. In deterministic deployment of the nodes the position of all the nodes in the network is known, and the data routing is done through the pre-determine path. However in random deployment, the sensor nodes are deployed randomly. Here the position of the nodes is not known so the routing path is difficult to determine. So, different routing algorithms are implemented for the fast and efficient transmission of the data through the nodes.

c) Energy Constraints: Lifetime of the sensor nodes depends upon battery of the sensor nodes. Each sensor nodes

has limited battery so the lifetime of the node is limited. The transmission power of a wireless radio is proportional to distance squared [3]. Energy consumed by multihop routing is less as compared to direct communication, but multihop routing will cause overhead. Direct communication is possible when all nodes are close to the base station [8].

d) Data Delivery model: The data delivered to the base station can be of different format depending upon the different applications. The data delivery model can be event-driven, continuous, hybrid and query-driven. In event driven model, data is transmitted when the event occurs. In continuous delivery model the sensor node sends data after some time interval. In query driven models the data is transmitted when query is generated by the base station. In hybrid model, it uses the combination of all the existing models. The routing protocol mostly depends on data delivery model, the aim of routing protocol is to minimize the energy consumption and maintain the network stability [4].

B) Designing of clustering protocol and their challenges

1) Designing of clustering protocol:

In the last few years, large number of clustering routing protocols has been developed. This paper presents is a review on clustering algorithms that have been developed for sensor networks. A few surveys of clustering methods for sensor network have been presented. Jiang et al. [7] discussed advantages of clustering methods for sensor network, such as more scalability, less overheads, and easy maintenance, and presents a classification of clustering schemes. The authors has analysed altogether six popular WSN clustering algorithms, such as LEACH, PEGASIS, HEED and EEUC and compared these WSN clustering algorithms, including various attributes. Tao Liu et al. [5] introduced a new type of routing protocol for called PECRP (Power-efficient Clustering Routing Protocol). PECRP is the combination of advantages of other cluster-based routing protocols such as HEED (Hybrid Energy-efficient Distributed Clustering Approach), PEGASIS (Power-Efficient Gathering in Sensor Information Systems). PECRP improves the mechanism for electing cluster heads. of LEACH. It elects appropriate cluster head, which could prolong the lifetime of WSN. PECRP uses multi-hop transmission for data transmission and balance the energy consumption in nodes. The simulations show that PECRP has better performances than LEACH in prolonging lifetime and transmitting data in the symmetrical distribution of nodes in WSN. Wendi Rabiner Heinzelman et al. [8] introduced communication protocols. This have a have significant impact on the energy overconsumption of the sensor networks. They find that the conventional protocols of direct transmission, minimum-transmission-energy, multi-hop routing, and static clustering may not be optimal for sensor networks. So they propose LEACH (Low-Energy Adaptive Clustering Hierarchy). It is a clustering-based protocol. This protocol uses randomized rotation of cluster-heads and energy is evenly distributed among the sensors in the network. LEACH enables scalability and robustness for dynamic networks. In routing protocol it does the data fusion in that it compresses the data and transmits it to the base station. Shin-Nosuke Toyoda et al. [9] introduced energy-efficient clustering algorithm considering adjacent nodes and residual electric power. Here in this method, all nodes except the sink node exchange the Hello message of each round. This message contains information of residual electric power and the adjacent node set. Thus, each node maintains the information of the adjacent node set and the residual electric power for the nodes. Firstly, the sink nodes select the first cluster head. Other cluster heads are selected by the first cluster head to cover the surrounding nodes. Thus this prevents flooding of the cluster head. Cluster head has been selected depending upon the remaining energy. The collections of the data from the node which cannot communicate with the sink node directly, these nodes use multi-hop routing communication of cluster head. Yong-Zhen Li et al. [11] introduced an improved LEACH algorithm called as LEACH-R. LEACH-R is classified into three steps: selecting cluster heads and transmission and cluster reappointment. LECH-R principle is similar with LEACH. In a cluster, cluster head collects the information from the different sensor nodes periodically. The base station assigns the different DS to each cluster and it assigns the TDMA gap to the nodes in each cluster. The algorithm does not depend on the number of nodes and the topology of the network. After the election of cluster head, it broadcast the message to all nodes and then it calculates the distance from itself to base station. The sensor node does the clustering depending upon the signal strength. The cluster head distributes TDMA slice to each node within its cluster. Thus the cluster establishment is complete. A survey of clustering algorithms for sensor network was presented by Abbasi et al. [4] proposed taxonomy and classification of clustering schemes, then summarized different clustering algorithms for sensor network. Different clustering approaches were compared based on a few metrics such as cluster stability, convergence rate, cluster overlapping, location-awareness and support for node mobility. Kalyana Tejaswi et al. [12] introduced two distributed clustering and multi-hop routing protocols i.e. CAMP and HBVR. CAMP (Clustering And Multi-hop Protocol) is a distributed clustering protocol, in which the cluster head had been selected dynamically by the node of the sensor network. Decision of electing the cluster head based on their local information. Now these nodes aggregate the data and then send the data to the base station. This is energy efficient method rather than sending the data individually to the base station. The second protocol introduced is HBVR (HEED with BVR). BVR (Beacon Vector Routing) is a point to point routing protocol. It maintains the link qualities while forming the neighbors. The neighbors of a node are decided by link quality. The nodes having same link quality as that of beacon nodes are considered. The nodes which have their hop count as 1, will in turn transmit beacon pulses. This procedure continues until every node in the network gets the virtually connected to coordinates with respect to the original beacon nodes.

2) Its Challenges

In wireless sensor networks, clustering protocol face several deployment challenges, such as ensuring connectivity, selecting the optimal cluster head rotation, and computing cluster sizes, and clustering network in the presence of a node duty cycle. Chunjuan Wei et al. [2] introduced various challenges in the clustering protocol. They are classified as:

a) Rotating the role of cluster head: In a cluster the normal sensor node transmits the data to the cluster head.

When the cluster head receives the data from all the sensor nodes in a cluster then it aggregates the data and forwards it to the base station. The cluster head selection depends on the various factors such has energy and connectivity [12]. When the CH sends the data to the base station some amount of its energy gets depleted. And if the CH in a cluster has no energy then the entire sensor node in that cluster will lose their connectivity. So for the next cycle other cluster head must be selected. S. Hussain et al. [13] proposed a genetic algorithm to form clusters in terms of parameters such as sum of all the distances from each sensor to the BS. Shahzad Ali et al. [14] introduced HEED protocol that periodically select CHs depending upon the residual energy of node and its node degree.

b) Optimal Cluster Size: In a network the cluster is of unequal size, in one cluster there are number of sensor nodes. But the number of sensor nodes in a cluster is not confined. In multi hope routing the CH communicates with other CH to forward the data to the base station. S. Lee et al. [16] introduced LUCA an Energy efficient Unequal Clustering Algorithm Using Location Information for Wireless Sensor Networks. Here each cluster is of different size based on its distance between a cluster head and a base station.

c) Mode of Communication Between SNs and CHs: In a sensor network the sensor nodes are organized in clusters, these nodes use either single-hop or multi-hop routing for communication to send their data to their respective cluster heads. There are various channel access methods such as TDMA, FDMA, CDMA and SDMA.

Figure: 2. Various channel access methods.

In TDMA, a specific time is allocated to a particular node and at that instance node uses entire bandwidth to transmit the data, no other node will transmit the data. This will avoid intercluster collision. Whereas in FDMA, the frequency bandwidth is divided, each node is given a slice of bandwidth and continuously sends data within this bandwidth. No other node will use the bandwidth of other node for communication. This scheme allows communication to be fast but collision can occur. In CDMA protocol, each node spreads its data using a unique pseudo-random noise sequence. Therefore, all nodes use the entire bandwidth at all times.

C. Designing of routing protocol

The selection of routing protocol is an important issue for the efficient delivery of the packets to their destination. Various energy-efficient routing protocols have been designed and developed for WSNs in order to support efficient data delivery to their destination. This paper presents the survey on several routing protocol in sensor network. And discuss the existing differences between the protocols.

1) Routing Protocol:

Kemal Akkaya et al. [3] introduced routing protocols for sensor networks and classify them into data-centric, hierarchical and location-based. It presents routing protocols for sensor network but it does not concentrate on the energy efficient policies. But we mainly focus on the energy-efficient routing protocols. In [17] Nikolaos A. Pantazis et al. concentrated on the energy efficient protocols that have been developed for WSNs. They classify them in flat, hierarchical, query-based, location-based.

a) Flat Routing Protocol: In a network all the nodes have the same function, all the sensor nodes perform the sensing task. Flat routing protocol has several advantages, minimal overhead between the nodes. Flat routing protocol, e.g., SPIN and directed diffusion saves energy through data negotiation and elimination of redundant data.

- SPIN: SPIN (Sensor Protocols for Information via negotiation) protocol uses data negotiation and resource-adaptive algorithms [15]. SPIN uses three types of messages:

ADV – advertise data,
REQ – request for data,
DATA – data message, it contains actual sensor data.

SPIN ha two main protocols i.e. SPIN1 and SPIN2. SPIN1 is a three way handshaking protocol. It uses the three messages: ADV, REQ and DATA. SPIN2 is the extension of SPIN1. It has energy constraint i.e. a threshold value. It can complete all the stages of the protocol above the energy threshold. If below energy threshold, node can receive the messages but cannot send or receive DATA messages [18].

- Directed diffusion: C. Intanagonwiwat et. al. [19], proposed data aggregation paradigm for WSNs, it is as called directed diffusion. Firstly, in directed diffusion process, the base station specifies a low data rate for incoming events. After that, the base station can reinforce one particular sensor to send events with a higher data rate by resending the original message in smaller interval. Likewise, if a neighbouring sensor receives this message and finds that the sender's interest has a higher data rate than the data rate sent before, then it will reinforce one or more of its neighbours.

b) Hierarchical Routing Protocol: In Hierarchical routing protocol, all the nodes in a network are organised in clusters. Here the node having higher energy is considered as cluster head. The cluster head is responsible for coordinating all activities within a cluster and transmits information between clusters. Clustering process helps in reduction of energy consumption and extends the lifetime of the network. The advantages of this routing protocol are energy efficient, scalability and stability [17]. Some of the hierarchical routing protocols are:

- LEACH: LEACH (Low-Energy Adaptive Clustering Hierarchy) is the first hierarchical protocol. It is adaptive and self-organizing clustering protocol in which sensor nodes organize themselves into clusters and the members in a cluster elects cluster head (CH) [20]. This reduces excessive energy consumption and uses data aggregation to reduce the amount of messages to be sent to the base station, this increase the lifetime of the network. Thus LEACH is an energy saving protocol.
- PEGASIS: PEGASIS (Power-Efficient Gathering in Sensor Information Systems) is an improvement over LEACH; it is a chain based protocol. PEGASIS construct chain of nodes instead of forming clusters. Each node communicates only with its closest neighbour and then transmits data to the base station, thus it reduces the amount of energy spent in each round [21].
- TEEN: TEEN (Threshold energy efficient sensor network) is the first protocol developed for reactive network. It is mostly used in temperature sensing applications [22]. TEEN divides sensor nodes twice for grouping cluster in order to detect the sudden changes in the attributes such as temperature. After the clusters are formed, TEEN divides the

Cluster Head into the second level Cluster Head. It uses hard and soft threshold to detect the changes. Hard threshold allows the node to transmit the event, if the event occurs within the range of sensed attributes. Unless a minor change of minimum soft threshold occurs, the node will not send a new data. Soft threshold prevents the redundant data transmission.

c) Query based Routing protocol: In Query based protocol, the base station executes a query for sending the data from the node in a network. Node having the required data sends the data to the destination.

d) Location based Routing Protocol: In this protocol the location information of the sensor node in the network is required. With this information it calculates the distance between two nodes and determines the signal strength and the amount of energy consumption can be estimated. It is used in routing data in energy efficient manner.

- GAF: GAF (Geographic Adaptive Fidelity) is adaptive fidelity algorithm. Here large numbers of sensor nodes are deployed in an area and only few nodes of that area are selected to transmit the messages, while the other nodes are in sleep mode. Thus, GAF saves nodes battery.
- GAER: GEAR (Geographic and Energy Aware Routing) uses neighbour information for selection of path that will be used to route a packet towards the destination. Thus, GEAR helps in balancing energy consumption and increases the network lifetime. When the destination is the closest neighbour then, GEAR forwards the data packet to the destination by just picking next-hop from all neighbours that are closer to the destination.

III. COMPARISON OF PROTOCOLS

The routing protocols that are explained in above section are compared. The advantages and disadvantages of these protocols are been discussed.

TABLE 1.CLASSIFICATION AND COMPARISON OF ROUTING PROTOCOLS IN WSN.

Routing Protocols	Classification	Advantaged	Drawbacks	Scalability	Route
LEACH	Hierarchical	Low energy, ad-hoc distributed protocol	Not applicable in large region, clustering brings overhead	Good	Shortest path
PEGASIS	Hierarchical	Transmitting distance is reduced	No consideration of base station when CH is selected	Good	Greed route selection
TEEN	Hierarchical	Works well where sudden changes occur	More energy consumption and overhead	Good	Best route
SPIN	Flat	Simplicity, minimum start-up cost	Time consuming	Good	Each node sends data to single hop
Direct Diffusion	Flat	Extend network life time	Cannot be used for continuous data transmission	Good	The best path
GAF	Location	Save node battery thus increase network life time	All nodes are not considered	Limited	The best path
GEAR	Location	Balance energy consumption thus increase network lifetime	The periodic table exchange	Limited	The best path

VI. CONCLUSION

In this paper we have discussed various energy efficient protocols in sensor networks. Firstly, we discussed about the architecture of sensor network which actually depends upon the application. The sensor network architecture is different for different application. Then we surveyed different clustering protocols. For communication between the sensor nodes and cluster head we have seen the some protocols; TDMA, FDMA, CDMA, SDMA. Out of this, TDMA is most appropriate approach. We have surveyed several clustering and routing protocols. We have also seen their challenges. So, for future research we can develop a protocol that will consume less energy for communication and will increase the lifetime of the sensor network.

So for that we can use clustering protocol to form clusters. And for communication within the cluster we can use TDMA protocol. For routing purpose we can use shortest cost path algorithm.

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