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A Review on Energy Efficient Routing Protocols & Techniques in Wireless Sensor Networks

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Abstract: ***Starting from the specific research objectives and deploying in the military operations, Wireless Sensor Networks (WSN) have numerous numbers of applications in every field these days. Due to amazing growth in the production of sensors and rapid evolution of MEMS (Micro-Electro-Mechanical-Systems) Technology, an interesting boost has been analyzed in this sector. The main purpose under any development is to minimize the size of a sensor node for it to be easily scattered across a target area and MEMS technology makes sensors smaller and cheaper. Recent advanced hardware technologies result in more powerful sensors as small as a few millimeters volume. The main drawback is still energy efficient routing constraints. With MEMS technology, we controlled the size of the sensor device but due to the applications of this technology in the remote areas but the problem of energy efficient routing is still there. Quality of service (QoS) is an important measure as energy efficiency in real time applications. Real time applications require guaranteed bandwidth and throughput throughout the working of the WSN. Along with the energy efficient routing techniques, the quality of service is equal important so this review paper focuses on all the energy efficient routing protocols, their advantages and disadvantages in reference to quality of service in the entire sensor network.***

Keywords: MEMS, Source node, destination node, multi-hop, Consequent Node, Efficient Routing and Minimum Transmission Energy.

I. INTRODUCTION

Wireless Sensor Networks are the networks which consist of thousands of multi-functioning sensors operating in a remote environment [1][2][3][4]. These networks consist of small battery powered devices with limited energy resources. In Wireless Sensor Networks, routing is the techniques of sending data from source node to destination by passing it to the adjacent node based on some mathematical calculation on distance or open path.

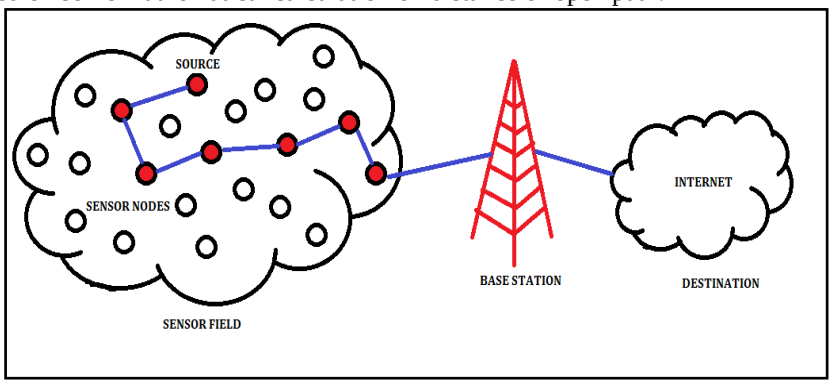

Fig. 1 Routing in Wireless Sensor Network

II. RECENT WORK

The common objective in routing in wireless sensor networks is to utilize the limited resources efficiently to enhance the lifespan of the entire network. Different routing techniques can be adopted for different applications based on their requirements and scenarios. Applications can be time critical or requiring periodic updates, they may require accurate data or long lasting network. They may also require continuous flow of data or event driven output. Routing methods can even be enhanced and adapted for specific application. There are so many routing techniques used in the wireless sensor networks, important categories of routing techniques are described below:

1) Data Centric Routing Techniques/ Flat Based Routing Techniques.
2) Cluster Based Routing Techniques/ Hierarchical Routing Techniques.
3) Location Based Routing Techniques.

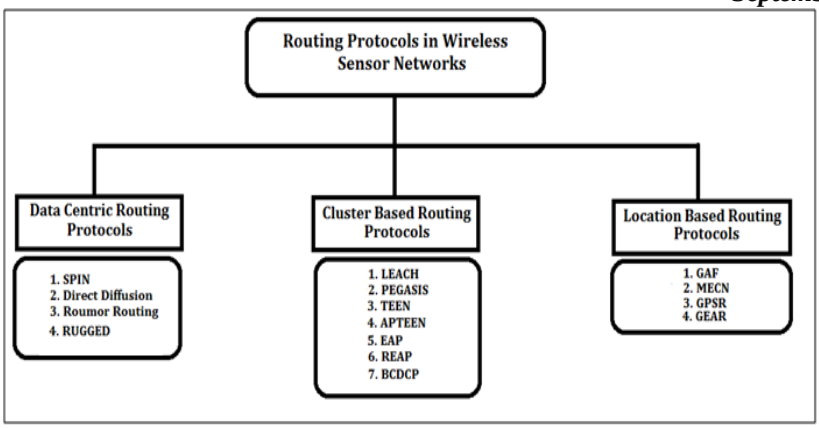

Fig.2 Routing Protocols in Wireless Sensor Network

Data Centric Routing Techniques [5]*:* Data centric routing techniques are also called Flat based Routing Techniques. In this technique, a large number of sensor nodes are deployed over a region making it inconceivable to assign a worldwide identifier for each node. This has led to the development of query based routing techniques known as data-centric routing protocols. In query based routing technique, the base station sends a query to a certain province in the network whose data is obligatory. The sensor nodes in the region aggregate their sensed data and route back to the base station along the overturn path revealed in the previous shift. The Examples of the data centric routing protocols are SPIN, Direct Diffusion routing protocol, Rumor routing protocol and RUGGED.

Sensor Protocol for Information via Negotiation (SPIN) [6]*:* SPIN is a protocol that was designed to enable data-centric information dissemination in sensor networks. Rather than blindly broadcasting sensor data throughout the network, nodes receiving or generating data first advertise this data through short ADV messages. The ADV messages simply consist of an application-specific meta-data description of the data itself. This meta-data can describe such aspects as the type of data and the location of its origin. Nodes that are interested in this data request the data from the ADV sender through REQ messages. Finally, the data is disseminated to the interested nodes through DATA messages that contain the data.

Direct Diffusion Routing Protocol [7]*:* C. Intanagonwiwat proposed a popular data aggregation paradigm for WSNs, called directed diffusion. Directed diffusion is a data-centric (DC) and application aware paradigm in the sense that all data generated by sensor nodes is named by attribute-value pairs.

Directed Diffusion is a data centric protocol which is recurrently used in Wireless Sensor Networks. This protocol consists of several elements like interests, gradients, data messages and reinforcements.

- An interest is a request in which it specifies the desired data sent by the base station to the sensor nodes.
- A gradient is a response link to the neighbor from which the interest was received.

Interests and gradients are described by attribute value model. When the sink requires a data, it broadcasts an interest containing several fields that depend on the application. Interests initially specify a low rate of data flow. Once a base station starts receiving events it will reinforce one (or more) neighbor in order to request higher data rate. This process precedes recursively until it reaches the nodes generating the events, causing them to generate events at a higher data rate.

On the other hand, routes may be negatively reinforced as well. Each node in the network maintains an interest cache which contains the information about the interest it received. Interest cache does not have information about the base station but the one-hop neighbor from which it received the interest. There are several fields in the interest cache as a time stamp field indicating the time stamp of the last event received. The interest cache also contains several gradient fields, up to one per neighbor. Each gradient contains the data rate field which specifies the data rate requested by the corresponding neighbor and also maintains a duration field.

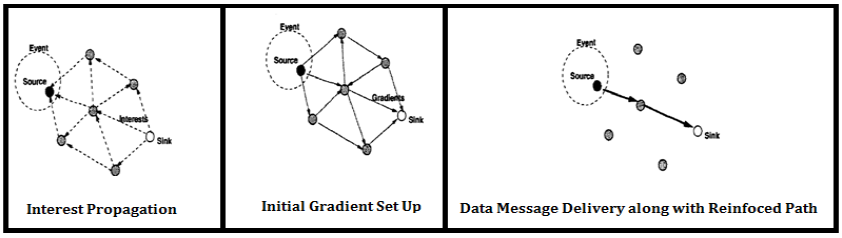

Fig. 3 Direct Diffusion Routing Protocol

Rumor Routing Protocol [8]: Rumor routing is a variation of directed diffusion and is mainly intended for applications where geographic routing is not feasible. Rumor routing is a WSN routing algorithm which aspires at lower energy deployment than algorithms that deluge the whole network with query or occurrence messages. The algorithm is tunable and its efficacy depends on the configuration parameters for the particular event and query allocation in the network. The

algorithm also handles node failures and allows for exchange between setup overhead and delivery reliability. These followings are the properties of this protocol:

- It is Agent-based path creation algorithm which is another variation of direct diffusion.
- This routing is between query flooding and event flooding.
- It route the query to the node one who has observed the event to occur rather than flooding to entire network as shown in following figure:

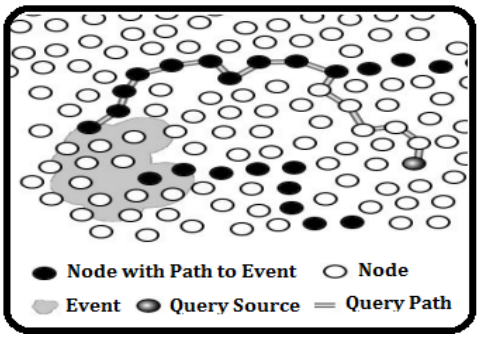

Fig. 4 Rumor Routing

- Rumor routing use long lived packet known as agent, created at random by nodes, and agent will die after visit k hops.
- Agent travel in the network to inform the distant nodes about local events
- When a node generates a query about event, the node which knows the route respond to the query by referring its event table.

RUGGED [9]: RUGGED is a gradient based routing protocol which stands for **RO**U**T**ING ON FIN**G**ERPRINT **G**RADIENT IN S**E**NSOR NETWORKS (RUGGED). RUGGED protocol routes the query to the event by effectively utilizing the finger print of the event. The most of the physical phenomena go after diffusion law with distance. Nothing like other information driven protocols, it eliminates the overload of preparing and maintaining the gradient information. RUGGED uses an environmental model in which the effect of the event follows a diffusion function with respect to both distance and time. Each corporeal event occurring in the environment results in a natural information gradient in the immediacy of the phenomenon. Such information gradient is known as fingerprint of the event caused by the events effect.

Cluster Based Routing Techniques [10][11]*:* Cluster based routing techniques are also known as hierarchical routing techniques. These are well-known techniques with special advantages related to scalability and efficient communication. Broadcasting is an important process for data transmission in wireless sensor networks. It is the process in which a source node transmits a message to all other nodes in the network. Clustering is one of the methods for Broadcasting, in this technique the cluster head is chosen and it will act as the leader for the cluster. It performs all the aggregation functions on the data which is forwarded by simple nodes. Now this aggregated data is forwarded to the base-station by the cluster head. The Examples of cluster based routing protocols are LEACH, PEGASIS, TEEN, APTEEN, EAP, REAP and BCDCP.

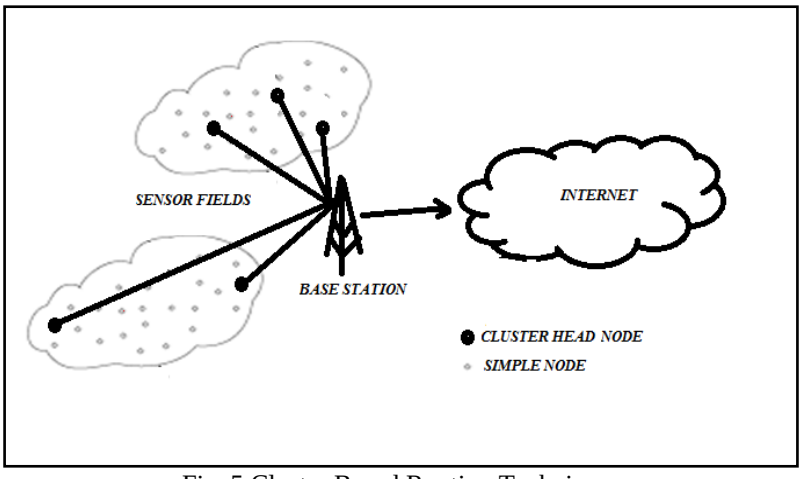

Fig. 5 Cluster Based Routing Techniques

Low Energy Adaptive Clustering Hierarchy Protocol (LEACH): The LEACH protocol was developed by three Ph. D. students named Wendi B. Heinzelman from MIT-Cambridge, Anantha P. Chandrakasan from University of California-Berkeley and Hari Balakrishanan from University of California- Berkeley in 2002. Low Energy Adaptive Clustering Hierarchy protocol is designed for sensor networks where an end-user wants to remotely monitor the wireless sensor environment. There are several desirable properties for protocols on these networks:

- ✓ Use 100's - 1000's of nodes
- ✓ Maximize system lifetime
- ✓ Maximize network coverage
- ✓ Use uniform, battery-operated nodes

LEACH protocol includes a new technique for distribution cluster formation that enables self-organization of large number of nodes, algorithm for adaptive cluster and rotating cluster head positions and a technique to enable distribution signal processing to save communication resources.

PEGASIS [12]*:* PEGASIS stands for Power-Efficient Gathering in Sensor Information Systems. It is a greedy chain protocol that is near optimal for a data- congregation problem in sensor networks. PEGASIS outperforms LEACH by eliminating the overhead of dynamic cluster formation, minimizing the distance non leader-nodes must transmit, limiting the number of transmissions and receives among all nodes, and using only one transmission to the BS per round. Nodes take turns to transmit the fused data to the BS to balance the energy depletion in the network and preserves robustness of the sensor web as nodes die at random locations. Although PEGASIS has certain drawbacks as it uses a greedy algorithm for the formation of data chain, it results Long Chain. Thus, consuming more energy due to which nodes die early. Data transmission will produce time-delay in PEAGSIS. Also the method of choosing the cluster head is not suitable for load balance.

TEEN [13]: TEEN stands for Threshold sensitive Energy Efficient sensor Network protocol. It is targeted at reactive networks and is the first protocol developed for reactive networks. The main features of this scheme are as follows:

- Time critical data reaches the user almost instantaneously
- Message transmission consumes much more energy than data sensing.
- The soft threshold can be varied, depending on the criticality of the sensed attribute and the target application.
- A smaller value of the soft threshold gives a more accurate picture of the network, at the expense of increased energy consumption.
- At every cluster change time, the attributes are broadcast afresh so the user can change them as required.

The main drawback of this protocol is that if the threshold values are not reached, the nodes will never communicate so the user will not get any data from the network at all and will not come to know even if all the nodes die. Therefore, this protocol is not well suited for applications where the user desires to get data on a conventional basis.

APTEEN [14]*:* The Adaptive Threshold Sensitive Energy Efficient Sensor Network Protocol (APTEEN) is an extension of TEEN and aims at both capturing periodic data collections and reacting to time critical events. The architecture is same as in TEEN. In APTEEN once the CHs are decided, in each cluster period, the cluster head broadcasts the parameter such as attributes, threshold, and schedule and count time to all nodes. A TDMA schedule is used and each node in the cluster is assigned a transmission slot. Hence, APTEEN uses a modified TDMA schedule to implement the hybrid network. The main features of the APTEEN scheme include the following. It combines both proactive and reactive policies. It offers a lot of flexibility by allowing the user to set the count-time interval (CT), and the threshold values for the energy consumption can be controlled by changing the count time as well as the threshold values. The main drawback of the scheme is the additional complexity required to implement the threshold functions and the count time.

EAP [15]*:* EAP Stands for Energy Aware routing Protocol. This protocol achieves a good performance in terms of lifetime by minimizing energy consumption for in-network communications and balancing the energy load among all the nodes. EAP introduces a new clustering parameter for cluster head election, which can better handle the heterogeneous energy capacities. Furthermore, it also introduces a simple but efficient approach, namely, intra-cluster coverage to cope with the area coverage problem. The operation of EAP is divided into rounds as LEACH. Each round begins with a set-up phase while clusters are organized and the routing tree is constructed, followed by a working phase when data are sent to the sink node.

REAP [16]*:* REAP is a ring band-based energy adaptive protocol for information dissemination and forwarding in wireless sensor networks. The basic idea of REAP revolves around the concept of ring bands. Nodes in REAP self-organize into a structure of ring bands, centered on the BS, in a way such that each node belongs to one ring band. Based on this organization, traffic is forwarded from an outer to an inner ring band until it reaches the BS.

BCDCP [17]*:* Base-Station Controlled Dynamic Clustering Protocol (BCDCP) is a wireless sensor routing protocol with the base station being an important component with complex computational abilities which makes the sensor nodes very simple and cost effective. In BCDCP, energy intensive computation decisions are taken by the BS, which is assumed to be non-energy constrained and to be fully aware of the location of all sensor nodes in the network. BCDCP builds uniformly distributed clusters and does not get confined to a particular region in the network.

Location Based Routing Techniques [18]*:* Routing algorithms based on geographical location is an important research theme in the Wireless Sensor Networks. They use location information to carry out routing detection and safeguarding as well as packet forwarding. Location based routing techniques are the techniques in which sensor nodes are addressed by means of their locations. The distance between adjoining nodes can be estimated on the basis of incoming signal strengths. Relative coordinates of adjoining nodes can be obtained by exchanging such information between adjoins.

Conventional techniques such as direct transmissions from any specified node to a distant base station have to be avoided in these networks since a large number of low-power sensor nodes have to be networked together. In the scenario of direct transmission, the nodes that are farther away from the base station will have their power sources drained much faster than those nodes that are closer to the base station. When a sensor node transmits data directly to the base station, the energy loss incurred can be quite extensive depending on the location of the sensor nodes relative to the base station. The base station serves as the destination node to all the other nodes in the network where the end user can access the sensed data. The solution to these problems is utilizing a conventional multi-hop routing scheme such as the Minimum Transmission Energy (MTE) routing protocol. There are so many routing protocols have been proposed and designed for Wireless Sensor Networks to lighten such problems. Data-centric routing is a frequently utilized approach that uses characteristic-based addressing to perform the collective sensing task. These following protocols are included in this category:

GAF [19]*:* Geographic Adaptive Fidelity (GAF) is Ad hoc routing protocol mainly for mobile & wireless networks. It is based on location information and tries to identify equivalent nodes for routing it hibernates unnecessary nodes. The physical space (network area) is divided into equal size squares known as zones based on nominal radio range. It forms a virtual grid. Any two nodes in adjacent squares can communicate with each other the nodes within a square are equivalent.

Nodes in the same virtual grid coordinate with each other they inform each other about the nodes status "who will sleep and for how long it will sleep" it tries to load balancing energy usage and all nodes remain up for us long as possible Node Ranking is needed each node estimates the time when it expects the leave the network which includes estimation in the discovery message. The main advantages of this protocol are given below:

- It is a highly customizable ad hoc routing protocol.
- Energy aware and Location based protocol which has reduces the energy consumption in WSN.
- Increase the network lifetime and each node knows its location with nodal distances.

The disadvantages of this protocol are as follows:

- This protocol does not care of QoS.
- The location information based on GPS
- There are scalability issues
- There needs to be dense node deployment

MECN [20]: Minimum Energy Communication Network (MECN) is self-reconfiguring protocol that tries to maintain network connectivity in spite of sensor's mobility. It achieves minimum energy for randomly deployed networks .It computes an optimal spanning tree known as minimum power topology. It works in two phases:

- Enclosure Graph Construction: Constructs directed sparse graph based on the immediate locality of the sensors
- Cost Distribution: high cost nodes are simply eliminated from graph and the resulting graph is a minimum power topology. Each sensor broadcasts its cost to its neighbors, where the cost of a node is the minimum power required for this sensor to establish a directed path to the sink.

The advantages of this protocol are as follows:

- It uses low power GPS.
- It is fault tolerant.

The disadvantage of this protocol is each GPS devices needs to be in synchronized mode.

GPSR [21]: GPSR stands for Greedy perimeter stateless routing for wireless networks. It is a responsive and efficient routing protocol for mobile, wireless networks. GPSR can be adapted to Wireless Sensor networks. Basically it tries to combine best features of algorithms, greedy forwarding algorithms and Perimeter Forwarding together to find the best path in a given topology. GPSR allows nodes to figure out who its closest neighbors are (using beacons) that are also close to the final destination the information is supposed to travel to destination. The main advantages of this protocol are given below:

- A node just has to remember the location of neighbors within one-hop.
- Routing decisions can be dynamically made.

The disadvantage of this protocol is it needs registration to Location Database on the network. This adds an overhead.

GEAR [22]*:* GEAR (Geographic and Energy Aware Routing) is based on query driven Protocols. Each node in GEAR keeps an estimated cost and a learning cost of reaching the destination through its neighbors. The estimated cost is a combination of residual energy and distance to destination. The process of forwarding packets towards target region depends on estimated and learned cost .it forwards packets within region using recursive geographic forwarding. GEAR uses energy aware neighbor selection to route a packet towards the target (1st phase of GEAR). Within a target region 2 different mechanisms are used to disseminate the packet (2nd phase of GEAR). The main advantages of this protocol are given below:

- Packets are routed to a "target region" instead of a particular node.
- Beforehand knowledge of Estimated cost and Learned cost (Can be used for preprocessing or pattern finding)

- Each node knows its location (e.g., via GPS) and the remaining energy level
- Each node knows the location and energy levels of its neighbors.

The main disadvantages of this protocol are given below:

- This protocol does not care of the QoS.
- This protocol uses static sensor locations (immobile)
- The links between nodes are bidirectional

III. FINDINGS

In this paper we have drawn a comparison between the different protocols which are energy efficient. In our findings we found that Cluster based routing preserves the energy consumption of wireless sensor nodes and performs data aggregation which helps in decreasing the number of transmitted messages to base station. Most of the routing protocols require location information for sensor nodes in wireless sensor networks to calculate the distance between two particular nodes on the basis of signal strength so that energy consumption can be estimated. There is data dissemination problems in most of the protocols designed for the Wireless sensor networks. The following table is classifying the comparison of the protocols.

Protocol	Category	Power Consumption	Energy Efficiency	Data Dissemination	Scalability	QoS	Additional Devices Required
SPIN	Data Centric	High	Poor	Yes	Limited	No	No
Direct Diffusion	Data Centric	High	Very Good	Yes	Good	No	No
RUGGED	Data Centric	High	Poor	No	No	No	No
Rumor Routing	Data Centric	Low	Good	Yes	No	No	No
LEACH	Cluster Based	Low	Very Good	Yes	Good	No	No
PEAGSIS	Cluster Based	Low	Very Good	Yes	Good	No	No
TEEN	Cluster Based	High	Good	Yes	Good	No	No
APTEEN	Cluster Based	Low	Very Good	Yes	Good	No	No
EAP	Cluster Based	Low	Good	No	Limited	Yes	No
REAP	Cluster Based	Low	Very Good	No	Limited	Yes	No
BCDCP	Cluster Based	High	Good	Yes	Good	No	No
GAF	Location Based	High	Poor	No	Limited	No	Yes (GPS)
MECN	Location Based	Low	Good	No	Limited	No	Yes (GPS)
GPSR	Location Based	High	Good	Yes	Good	No	Yes (GPS)
GEAR	Location Based	High	Good	No	Good	No	Yes (GPS)

IV. CONCLUSION

There are so many excellent protocols have been designed and developed for Wireless Senor Networks. There is need to design scalable, energy efficient routing protocols which improves efficiency of both ad-hoc and sensor networks. The number of applications that can benefit from efficient routing is impressive. Due to various constraints like topology, mobility, time constrictions, effervescent node structure, non deterministic nature of the links and resource constrained environment of Wireless Sensor Networks, energy efficient routing is quite exigent to meet the needs of Real time processing systems. In this paper we surveyed widely used routing protocols along with their key features so that we can able to choose the best protocol according to constraints. However many issues of routing still needs to be addressed. It is very difficult to create all purpose routing protocols.

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