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Energy-Efficient Routing Protocols for Wireless Sensor Network: A Survey

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Abstract*— Wireless sensor networks have recently received tremendous attention from both academia and industry because of their promise of numerous potential applications in both civilian and military areas. A wireless sensor network consists of a large number of small sensor nodes with sensing, data processing, and communication capabilities, which are deployed in a region of interest and collaborate to accomplish a common task, a sensor network has many unique characteristics, such as denser node deployment, higher unreliability of sensor nodes, asymmetric data transmission, and severe power, computation, and memory constraints, which present many new challenges for the development and eventual application of wireless sensor networks. In particular, sensor nodes are usually battery-powered and should operate without attendance for a relatively long period of time. In most cases, it is very difficult and even impossible to change or recharge batteries for these sensor nodes. Thus, energy-saving routing protocol in wireless sensor networks is necessary for increasing the network lifetime. In this paper we present a comparative study of different routing algorithms and analysis of same is presented in the paper.

***Index Terms*- Energy-Efficient Routing, Overhead, MAC, Wireless Sensor Networks (WSN), Balancing Energy Consumption, And Potential Field.**

I. INTRODUCTION

Recent advances in wireless communications and electronics have enabled the development of low cost, low-power, multifunctional sensor nodes that are small in size and communicate untethered in short distances. These tiny sensor nodes, which consist of sensing, data processing, and communicating components, leverage the idea of sensor networks. Sensor networks represent a significant improvement over traditional sensors. A sensor network is composed of a large number of sensor nodes that are densely deployed either inside the phenomenon or very close to it. The position of sensor nodes need not be engineered or predetermined. This allows random deployment in inaccessible terrains or disaster relief operations. On the other hand, this also means that sensor network protocols and algorithms must possess self-organizing capabilities. Another unique feature of sensor networks is the cooperative effort of sensor nodes. Sensor nodes are fitted with an onboard Processor. Instead of sending the raw data to the nodes Responsible for the fusion, they use their processing abilities to locally carry out simple computations and transmit only the required and partially processed data.

A. Routing

It is the process of establishing path and forwarding packets from source node to destination node. It consists of two steps, route selection for various source-sink pairs and delivery of data packets to the correct destination. Various protocols and data structures (routing tables) are used to meet these two steps. This survey paper is focused on finding and selecting energy efficient routes. We are going to discuss the four approaches in the routing. These are proactive, reactive, hybrid and location based routing

B. Energy Efficient Routing

Energy is a limiting factor in case of WSN. Routing in WSN has some unique characteristics.

- *First*- Energy of nodes is crucial and depends upon battery which has limited power supply.
- *Second*- Nodes can move in an uncontrolled manner so frequent route failures are possible.
- *Third*-Wireless channels have lower and more variable bandwidth compare to wired network

Energy efficient routing protocols are the only solution to above situation. Most of the work of making protocols energy efficient has been done on "on demand routing protocols" because these protocols are more energy efficient rather than proactive protocols but still these have some drawbacks which have been discussed in the next section. Energy efficiency can also be achieved by sensible flooding at the route discovery process in reactive protocols. And energy efficiency can also be achieved by using efficient metric for route selection such as cost function, node energy, battery level etc. Here energy efficiency doesn't mean only the less power consumption here it means increasing the time duration in which any network maintains certain performance level. We can achieve the state of

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energy efficient routing by increasing the network lifetime and performance and all the protocols discussed in this paper are based on this concept.

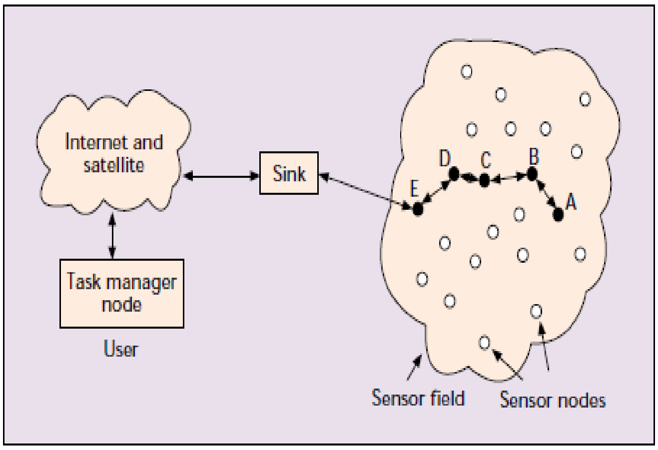

Fig. 1 Typical Architecture Of WSN

II. CLASSIFICATION

Routing protocols can be classified according to various approaches which are as follows:

A. Proactive Routing

Proactive protocols continuously evaluates the routes within the network so that when we are required to forward the packet route is already known and immediately ready for use. There is no time delay (time spend in route discovery process) takes place. So a shortest path can be find without any time delay however these protocols are not suitable for very dense ad-hoc networks because in that condition problem of high traffic may arise. Several modifications of proactive protocols have been proposed for removing its shortcomings and use in ad-hoc networks. It maintains the unicast routes between all pair of nodes without considering of whether all routes are actually used or not. It can be of two types depending upon the algorithms which have been shown in the next section. In link state proactive protocols each node maintains a view of the network topology and it stores the cost of each outgoing links and periodically broadcast its link costs via flooding. In distance vector proactive protocols each node maintains a routing table which contains the cost of every node of the network, next node to reach the destination and the total no of nodes to reach the destination and this routing information table is send to all neighbors to maintain the topology. Examples of the proactive protocols are – DSDV (Destination-Sequenced Distance-Vector), Wireless Routing Protocol, and Optimized Link State Routing, TBRPF.

B. Reactive routing

It is also called on demand routing. it is more efficient than proactive routing and most of the current work and modifications have been done in this type of routing for making it more and more better. The main idea behind this type of routing is to find a route between a source and destination whenever that route is needed whereas in proactive protocols we were maintaining all routes without regarding its state of use. So in reactive protocols we don’t need to bother about the routes which are not being used currently. This type of routing is on demand. Discovering the route on demand avoids the cost of maintaining routes that are not being used and also controls the traffic of the network because it doesn’t send excessive control messages which significantly create a large difference between proactive and reactive protocols. Time delay in reactive protocols is greater comparative to proactive types since routes are calculated when it is required. e.g. Ad-hoc On Demand Distance Vector (AODV), Dynamic Source Routing (DSR).

C. Hybrid Routing

Both of the proactive and reactive routing methods have some advantages and shortcomings. In hybrid routing a combination of proactive and reactive routing methods are used which are better than the both used in isolation. It includes the advantages of both protocols. As an example facilitate the reactive routing protocol such as AODV with some proactive features by refreshing routes of active destinations which would definitely reduce the delay and overhead so refresh interval can improve the performance of the network and node. These protocols can incorporate the facility of other protocols without compromising with its own advantages. Examples of hybrid protocols are Zone Routing Protocol, Hazy Sighted Link State.

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D.Location based routing

All of the above approaches share a common feature of discovering topology information with the help of routing messages and the further discovery of any other route uses this information with the help of routing tables. Location based routing is completely different from above these methods. It acquires a completely different approach that utilizes the global information of the nodes. This type of routing assumes that each node of the network is having a GPS installed in it. So, each node knows its own global position by using this GPS system or any other localization technology. It doesn't need any type of route discovery or route maintenance algorithms. This gathers the knowledge of other node's locations without transferring request messages. This only sends hello messages to its neighbours to know their global position. It is efficient when topology of the network changes frequently. e.g. Location Aided Routing, Distance Routing Effect Algorithm for Mobility (DREAM).

III. ENERGY EFFICIENT ROUTING PROTOCOLS

In this section we have studied following energy efficient routing protocols.

A.Ad Hoc On Demand Distance Vector (AODV)

The Ad hoc On Demand Distance Vector (AODV) routing algorithm is a routing protocol designed for ad hoc mobile networks. AODV is capable of both unicast and multicast routing. It is an on demand algorithm, meaning that it builds routes between nodes only as desired by source nodes. It maintains these routes as long as they are needed by the sources. Additionally, AODV forms trees which connect multicast group members. The trees are composed of the group members and the nodes needed to connect the members. AODV uses sequence numbers to ensure the freshness of routes. It is loop-free, self-starting, and scales to large numbers of mobile nodes. The AODV protocol uses *route request* (RREQ) messages flooded through the network in order to discover the paths required by a source node. An inter-mediate node that receives a RREQ replies to it using a *route reply* message only if it has a route to the destination whose corresponding destination sequence number is greater or equal to the one contained in the RREQ. The RREQ also contains the most recent sequence number for the destination of which the source node is aware. A node receiving the RREQ may send a route reply (RREP) if it is either the destination or if it has a route to the destination with corresponding sequence number greater than or equal to that contained in the RREQ. If this is the case, it uncast a RREP back to the source. Otherwise, it rebroadcasts the RREQ. Nodes keep track of the RREQ's source IP address and broadcast ID. If they receive a RREQ which they have already processed, they discard the RREQ and do not forward it. As the RREP propagates back to the source nodes set up forward pointers to the destination. Once the source node receives the RREP, it may begin to forward data packets to the destination. If the source

*1. **Advantages and Disadvantages***

The main advantage of AODV protocol is that routes are established on demand and destination sequence numbers are used to find the latest route to the destination. The connection setup delay is less. The HELLO messages supporting the routes maintenance are range limited, so they do not cause unnecessary overhead in the network. One of the disadvantages of this protocol is that intermediate nodes can lead to inconsistent routes if the source sequence number is very old and the intermediate nodes have a higher but not the latest destination sequence number, thereby having stale entries. Also multiple Route Reply packets in response to a single Route Request packet can lead to heavy control overhead Another disadvantage of AODV is that the periodic beaconing leads to unnecessary bandwidth consumption.

B.Dynamic Source Routing (DSR)

Dynamic Source Routing (DSR) is a routing protocol for wireless mesh networks and is based on a method known as *source routing*. It is similar to AODV in that it forms a route on-demand when a transmitting computer requests one. Except that each intermediate node that broadcasts a route request packet adds its own address identifier to a list carried in the packet. The destination node generates a route reply message that includes the list of addresses received in the route request and transmits it back along this path to the source. Route maintenance in DSR is accomplished through the confirmations that nodes generate when they can verify that the next node successfully received a packet. These confirmations can be link-layer acknowledgements, passive acknowledgements or network-layer acknowledgements specified by the DSR protocol. However, it uses source routing instead of relying on the routing table at each intermediate device. When a node is not able to verify the successful reception of a packet it tries to retransmit it. When a finite number of retransmissions fail, the node generates a route error message that specifies the problematic link, transmitting it to the source node. When a node requires a route to a destination, which it doesn't have in its route cache, it broadcasts a *Route Request (RREQ)* message, which is flooded throughout the network. The first RREQ message is a broadcast query on neighbors without flooding.

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*1. **Advantages and Disadvantages***

DSR uses a reactive approach which eliminates the need to periodically flood the network with table update messages which are required in a table-driven approach. The intermediate nodes also utilize the route cache information efficiently to reduce the control overhead. The disadvantage of DSR is that the route maintenance mechanism does not locally repair a broken down link. The connection setup delay is higher than in table-driven protocols. Even though the protocol performs well in static and low-mobility environments, the performance degrades rapidly with increasing mobility. Also, considerable routing overhead is involved due to the source-routing mechanism employed in DSR. This routing overhead is directly proportional to the path length.

C. Energy Dependent DSR (EDDSR)

EDDSR [8] is energy dependent DSR algorithm which helps node from sharp and sudden drop of battery power. EDDSR provides better power utilization compare to LEAR (least energy aware routing) and MDR (minimum drain rate). EDDSR avoids use of node with less power supply and residual energy information of node is useful in discovery of route. Residual battery power of each node is computed by itself and if it is above the specific threshold value then node can participate in routing activities otherwise node delays the rebroadcasting of route request message by a time period which is inversely proportional to its predicted lifetime. With help of ns-2 simulator author performed simulation which shows MDR and EDDSR is better than DSR in terms of node lifetime. EDDSR has further advantage over MDR because it can use route cache used by DSR

D. Location Aided Routing (LAR)

LAR [14] (Location Aided Routing) protocol is one of the most important and popular geographical based routing protocol for wireless mobile Ad-hoc networks. LAR is based on sensible flooding. In flooding source node broadcasts the route request to its neighbours. These nodes check there identification with destination. If a match occurs destination is found otherwise they re-broadcast the message to their neighbours. Whenever any node gets the broadcast for first time it re-broadcast it. So broadcast moves outwards from source .This broadcast is terminated when every node has got the message and transmitted it once. Using unique identifier with each packet helps in avoiding loops. We don't have to maintain any topological information in case of flooding. Flooding sometimes becomes very inefficient because to transfer a single message from source to destination total number of transmissions is in the order of network size. LAR is used to reduce the flooding overhead with help of location information of nodes. Location information of node can be achieved with help of global positioning system [GPS]. There is some amount of error in location information obtained from GPS but with the advancement in this technology this error is reduced significantly. Now real coordinates and GPS computed coordinates are quite similar. In LAR it is assumed that nodes are moving in 2-Dimensional plane. LAR applies the concept of Expected Zone and Request Zone. The expected zone is the area where destination node can be found calculated with help of its location information and speed. Additional information like direction of movement can help in reducing the size and increasing the accuracy of expected zone. Request zone include expected zone as well as other regions around the expected zone. Route request can be forwarded by those nodes only which belong to this request zone. So a restriction on flooding is applied to increase the efficiency of protocol. There are two variations to decide the membership of request zone: -LAR scheme 1 and LAR scheme 2. First LAR scheme request zone is the smallest rectangle which includes source and expected zone. This rectangle is parallel to X and Y axis. Much variation regarding the area selection is also proposed by various researchers. We can also select the rectangle which is parallel to line connecting source and destination. In second LAR scheme source forwards the route requests to only those nodes that are nearer to destination by comparing the required destinations.

E. Localized Energy Aware Restricted Neighborhood Routing (LEARN)

LEARN [16] is an energy efficient routing protocol proposed by Y. Wang, W. Song, X. Li, T. Dahlberg. This routing algorithm theoretically guarantees the power efficiency of its route asymptotically almost sure. If destination node is t, any intermediate node u will only choose a particular neighboring node v if $\angle vut \leq \alpha$ for a parameter $\alpha < \pi/3$ in learn method. They theoretically show that for a network, formed by nodes that are produced by a Poisson distribution with rate n over a compact and convex region Ω with unit area, when the transmission range rn= $\{\beta \ln n/\pi n\}^{1/2}$ for some $\beta > \pi\alpha$, LEARN routing protocol will find the route for any pair of nodes asymptotically almost sure. When the transmission range rn = $\{\beta\, l_n\, n/\pi_n\}^{1/2}$ for some $\beta < \pi\alpha$, the LEARN routing protocol will not be able to find the route for any pair of nodes asymptotically almost sure.

F. Temporally Ordered Routing Algorithm (TORA)

TORA is a distributed routing protocol for mobile, multi-hop wireless networks. Its intended use is for the routing of IP datagram's within an autonomous system. The basic, underlying algorithm is neither a distance vector nor a link state; it is one of a family of algorithms referred to as "link-reversal" algorithms. The protocol's reaction is

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structured as a temporally ordered sequence of diffusing computations, each computation consisting of a sequence of directed link reversals. The protocol is highly adaptive, efficient, and scalable, and is well suited for use in large, dense, mobile networks. In these networks, the protocol's reaction to link failures typically involves only a localized "single pass" of the distributed algorithm. This desirable behavior is achieved through the use of a physical or logical clock to establish the "temporal order" of topological change events. The established temporal ordering is subsequently used to structure (or order) the algorithm's reaction to topological changes.
TORA's design is predicated on the notion that a routing algorithm that is well suited for operation in this environment should possess the following properties:

- Executes distributedly.
- Provides loop-free routes.
- Provides multiple routes (i.e., to reduce the frequency of reactions to topological changes, and potentially to alleviate congestion).
- Establishes routes quickly (i.e., so they may be used before the topology changes).
- Minimizes communication overhead by localizing algorithmic reaction to topological changes when possible (i.e., to conserve available bandwidth and increase scalability).

Routing optimality (i.e., determination of the shortest path) is of less importance. It is also not necessary (or desirable) to maintain routes between every source– destination pair at all times. The overhead expended to establish a route between a given source–destination pair will be wasted if the source does not require the route prior to its invalidation due to topological changes. TORA is designed to minimize reaction to topological changes. A key concept in its design is that it decouples the generation of potentially far-reaching control message propagation from the rate of topological changes. Control messaging is typically localized to a very small set of nodes near the change without having to resort to a dynamic, hierarchical routing solution with its attendant complexity. TORA includes a secondary mechanism, which allows far-reaching control

IV. CONCLUSION

In this survey paper we discussed a lot of conventional protocols and their modification which includes energy efficiency with the importance of energy efficient routing protocols. We conclude that there is not a single protocol which can give the best performance in ad-hoc network. We have also discussed the factors that can be improved to increase the routing efficiency. Performance of the protocol varies according to the variation in the network parameters. Sometimes the mobility of the node of the network is high sometimes energy of the node is our prime concern, We have discussed that in which type of network environment these protocols will perform better and for which type of networks these are not suitable. The comparisons of these energy efficient protocols have been shown in this survey paper. We have tried to present almost all possible approaches of energy efficient protocols.

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