ISSN No. 0976-5697

Volume 4, No. 3, March 2013 (Special Issue)

International Journal of Advanced Research in Computer Science

REVIEW ARTICLE

Available Online at www.ijarcs.info

A Brief Review on Routing in Wireless Sensor Networks

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Abstract: In the last few years the craze of the wireless sensor network (WSN) is increasing and it has become a latest field of research. Protocols used in ad-hoc networks cannot be used in sensor networks because the sensors are tiny in size, have limited battery power, less storage capacity. Hence new protocols are generated for sensor networks. One of the major challenges is to design an energy efficient routing strategy for WSN. In this paper, metric evaluation, designing issues of the sensor routing protocols are discussed. Routing in WSNs can be broadly sub divided in two categories: flat routing and clustering or hierarchical routing. In this paper, several routing schemes are discussed along with some energy aware cluster routing methods.

Keywords: Ad-hoc network, metrics, clustering.

I. INTRODUCTION

Sensor networks are small, lightweight wireless nodes deployed in large quantity to monitor system or environment. It monitors temperature, pressure, or relative humidity. Sensor node comprises of micro-electro mechanical system (MEMS) [1]. Sensor nodes have three subparts, first for sensing environment, second to perform computation on sensed data, third to transfer processed or computed data to sensor nodes till base station. It has limited sensing capability, low processing power and are low energy devices. It shows better fault-tolerance by sensing the same event through many nodes. In WSN, two most important operations are performed, first, it propagates data/query throughout the network through data dissemination and secondly, the collection of observed data from each sensor to sink through data gathering. Sensor network senses by different types of sensors: seismic, thermal, visual and infrared. Sensor nodes used in military, medical science and disaster. Sensor will be a part of our daily life such as in commercial applications at home and industries. Smart sensor nodes can be used in ovens, refrigerators and vacuum cleaners which are managed by remote control. Applications of sensor networks are thus endless, limited only by human imagination.

II. DESIGN ISSUES IN SENSOR NETWORK

Wireless sensor networks are highly distributed system [2]. These are deployed in many fields but have some shortcomings. So, it is necessary to concentrate on some design issues in designing of WSN. Design issues are broadly divided in three parts:

A. Routing challenges and design issues in WSN:

a. ***Fault tolerant Communication:*** Sensor nodes are deployed in unrestrained environment. Some nodes cannot communicate with each other so those nodes become faulty and unreliable. Thus such framework gives hardwearing to the coming on of faulty nodes.

b. ***Low latency:*** In this issue the framework dealing with an event should acknowledge quickly to theoperator .

c. ***Management at a Distance:*** Sensor nodes are deployed in such areas where it is difficult manage directly such network. So this framework should be indirectly managed through remote control / management system.

d. ***Scalability:*** To increase sensor nodes upto hundred and thousand, the routing algorithms and system should support such an advancement in the system. Scalability can be measured in various dimensions.

e. ***Transmission media:*** In multi-hop sensor network, nodes communicate through wireless medium. So some problems such as fading and high error probability may affect the operation of sensor nodes.

f. ***Coverage problem:*** This is the basic parameter in sensor networks by which quality of any network can be defined.

g. ***Network Scale and Time-Varying Characteristics of WSN:*** Nodes have limited energy constraints, computing, storage and communication capabilities [3]. WSN dense and sparse depend upon the type of application. Sensor nodes also give better performance in environments such as

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noisy, erratic and unpredictable, radio-frequency interference.

B. Topology Issues of WSN:

a. ***Geographic Routing:***Geographic routing depends upon the geographic position information. It sends the location information of the destination instead of the network address. For efficient routing and low power consumption, geographic routing algorithms use geography and topology information of the network.

b. ***Sensor Holes:***A hole in a region means sensor nodes are not present in that area or the available nodes cannot participate in the actual routing [4]. If in an application target area is not covered properly then it is required to find out the sensor nodes of that hole.

c. ***Coverage Topology*:** Coverage problem is that how well an area is monitored or tracked by sensors. Researcher are recently trying to solve the coverage area problem. The main aim is how to cover maximum area by 'k' sensor where 'k' is given parameter.

d. ***Available Topologies:***Several network topologies to coordinate the WSN gateway, end nodes and router nodes of star topology, where each node should directly connect to gateway node but for distance it will not work .[5]. To increase a network coverage properly; clustering, tree topology are better solutions. In this topology, a problem is that if a router node goes down, all node which are dependent on that router, lose their communication path.

The mesh topology reduce this problem and increase the reliability of the network. In this network if one router goes down then another communication path is developed by another routers.

C. Quality of Service support in WSN:

The main aim of Qualities of service (QOS) is to provide better networking services over current technologies. The main parameter are:

a. ***Delay, Jitter and Loss:***Delay is defined as the amount of time a frame takes to travel from source to destination. Jitter is delay between two consecutive packets in that frame. Loss is defined as number of packet that is lost in that stream. So network algorithms are designed such that packets must reach at the destination minimizing the delay, jitter, packet loss.

b. ***Reliability and scalability:***In wireless sensor networks reliability and scalability are inverse of each other. If number of nodes are increased the reliability of network is decreased. Due to changing shape and topology the network must generate more control packets than data packets.

c. ***Responsiveness:***The network should have the capability to respond to changes in the shapes and topology. To achieve this, network has to exchange more control packets. So it becomes less scalable and reliable.

d. ***Power Efficiency:*** Power efficiency is another important issue to design a low power wireless sensor network which reduces the duty cycle of nodes. And keeps many nodes in sleep mode for saving the energy or power of a network but by this it creates the problem of responsiveness to communicate neighbors.

e. ***Mobility:*** Mobility is another issues where nodes have to communicate with each other because of which communication is problematic. But it gives better coverage.

f. ***Bandwidth:***Bandwidth is defined as range of any communicating entity. Higher bandwidth gives better performance.

III. METRICS FOR WSN

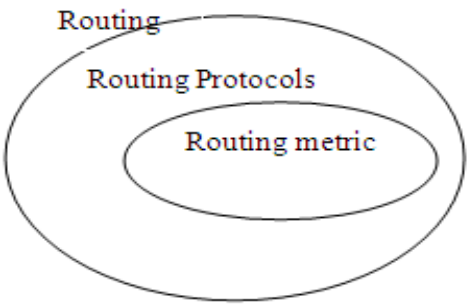

Figure 1:Relationship between Routing Protocol and a Routing Metric in WSNs.

A. General Metrics:

General metrics are for the evaluation of real time and non real time routing protocols in WSN

a. ***Network Lifetime (LSN):***- The main goals of routing protocols is to increase the life time of the sensor network (LSN). Whenever the sensor network partition of sensor nodes goes down at threshold level then maximum number of queries are handled successfully by sensor network in its life time [6].

b. ***Routing Load:***Routing load is defined as the ratio of number of routing packets and data packets transmitted. Mainly notices that how many data packets are reached at the destination successfully and bandwidth used in delivering those number of data packets [7].

c. ***Energy/Power Consumption (EC/PC):***Energy consumption shows that how much the routing protocols are energy efficient for individual sensor [6]. Energy is equal to sending and receiving data.

d. ***Routing Overhead(Packets*):**It is the ratio of total number of packets generated and sum of total number of data packets transmitted and total number of routing packets [7].

e. ***Load Imbalance Factor(LIF):***The time taken by nodes in routing decision is called lifetime of sensor.If time is more in routing then power down of sensor thus load is imbalance of network. So, the routing protocol should be such that it will balance the load [6].

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f. ***Ratio Traffic Overhead:*** Ratio Traffic overhead is the ratio of the number of bits per second which the network uses to forward the useful bits from the source to the destination [8].

g. ***Throughput or Packet Delivery Fraction*****:** It means numbers of bits are delivered at the destination in given period of time successfully higher throughput means better performance of protocol. It is also called Packet Delivery Fraction (PDF) [9].

h. ***Ratio of Corrupted Pings:***These are control packets that are not recognized by the destination node and considered as received corrupted packets [8].

i. ***Route Discovery Time*****:** Route discovery time is the time the sink must wait before actually receiving the first data packet.

j. ***Route Maintenance and Fault Tolerance:***Route maintenance is the process in which whenever a route link is broke or topology is changed then from source to destination route maintenance done for detects changes in network and find the new route. When sensors fail in the network, then holes are created that is difficult to fill and thus there should be provision in algorithm to prevent formation of such holes for proper working of the network.

k. ***Average Path Length:*** Average Path Length means shortest path from source to destination.

l. ***Average End to End Delay of Data Packets:***It means average time of packet that are transfered successfully from source to destination here, measuring delay of queuing, retransmission delay at MAC layer propagation and transfer time.

m. ***Number of Failed Sensor:*** When some sensors failed then their load should be handled by another sensors node by doing load balancing method.

n. ***Path length Extension Rate (PLER*****):** In routing, protocol always choose shortest path but for balance load, It has to choose extended path. It was defined by extension rate which compares extended path length with GPSR. The Average Extended Path length is given as follows:

$PLER = PL_{Others} + PL_{GPSR}$

Query Successful Delivery Rate (QSDR) and Reply Successful Deliver Rate (RSDR):

During routing process, some time query/reply is failed due to failure of sensors. If node's length exceeds then message has to deliver. Query successful delivery rate and reply is a metric which shows success rate of message delivery and reply. It shows fault tolerance of routing protocol.

o. ***Average Route Acquisition Latency:***It is latency discover destination by RREQ packets and RREP from destination delay taken by network.

Average Route Acquisition Latency = computation Cost + Communication Cost

B. Security Metric:

a. ***Resiliency:***The goal of resiliency is to design such routing protocol that provides security against various known attack, it does not give information about pair keys. This metric ensures that attacker cannot compromise the entire WSN.

b. ***Connectivity:***This is the probability for communication of a node with other node in WSN.

C. Link Quality Metrics

a. ***Expected Transmission Count (ETX):*** ETX minimizes the number of transmission for data packet. It was first was developed for ad hoc network but also used in sensor networks as well. By measuring the delivery rate of beacon packets between neighboring nodes; it can find out the number of transmissions that are needed. It concentrates on link quality and energy consumption estimate [10].

b. ***Requested Number of Packets (RNP):***RNP is a metric for low power wireless links. The RNP is measured as number of transmissions needed in an Automatic Repeat Request (ARQ) underlying packet loss distribution [10].

IV. ROUTING PROTOCOLS IN WSNS

Table: 1

Category	Representative Protocols
Location-based Protocols	MECN, SMECN, GAF, GEAR, Span, TBF, BVGF, GeRaF
Data-centric Protocols	SPIN, Directed Diffusion, Rumor Routing, COUGAR,ACQUIRE, EAD, Information-Directed Routing, Gradient-Based Routing, Energy-aware Routing, Information-DirectedRouting, Quorum-Based Information Dissemination, Home Agent Based Information Dissemination
Hierarchical Protocols	LEACH, PEGASIS, HEED, TEEN, APTEEN
Mobility-based Protocols	SEAD, TTDD, Joint Mobility and Routing, Data MULES,Dynamic Proxy Tree-Base Data Dissemination
Multipath-based Protocols	Sensor-Disjoint Multipath, Braided Multipath, N-to-1Multipath Discovery
Heterogeneity-based Protocols	IDSQ, CADR, CHR
QoS-based protocols	SAR, SPEED, Energy-aware routing

Based on structure, routing protocols in WSN roughly divided in two categories: Flat routing and hierarchical routing. In the flat routing flooding is done and data is transferred hop by hop but it is better only for small scale networks. And in hierarchical routing, the whole network is divided into clusters and each cluster has a cluster head (CH) and other member nodes (MNs) or ordinary nodes (ONs), CHs can also organize into further hierarchical levels. Here CH nodes perform all activities such as processing and forwarding [11]. Recently concentration is given on cluster routing protocols because cluster routing protocol have some advantages as they facilitate the network with more scalablility, data aggregation/Fusion, less load, less energy consumption, more robust, collision avoidance, latency reduction, load balancing, fault tolerance, guarantee of connectivity, energy hole avoidance by this advantages the cluster routing algorithm are used [12].

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In this paper concentration is on energy efficient routing protocols and some algorithm stage protocols are as follows:

A. Cluster-Construction Based Clustering Routing Protocols:

a. Low-Energy Adaptive Clustering Hierarchy (LEACH):was proposed by Heinzelman et al. [13], was the most basic fundamental routing protocol. In LEACH the CHs are selected on rotation, so high energy is which for communicating for the base station is spread to all nodes in network. LEACH comprises of many rounds and each round is further divided into two phases, the set-up phase and steady-state phase. In set-up state all nodes are organized to decide the cluster head. If any node have been already CH in network chance of that depend upon choosing by random number between 0 to 1 apply threshold that is an equation, if value is less then threshold, the node then become CH. It broadcasts CH's to other nodes. According received signal strength of advertise nodes decides to join that CH and send membership message to CH. In second steady state all nodes sensed data and send to CH, CH compress data and direct deliver to the BS. After certain time, network again in set-up phase.

Advantages of LEACH as any node that became CH in some round chances of that is less, so every node has equally shared load is somewhat distributed. Using a TDMA schedule reduces collisions. In this protocol time slot is given to member node according to which it starts and stops communicating. Some disadvantage in LEACH protocol are that the CHs directly send data to BS which is not suitable for large networks due to the fact that network depend on radio range and lead to much energy consumption. CHs are selected based on probabilities not on the energy level of node so it may assume that in real-time itcannot perform load balancing. Election is based on the probabilities then it is not necessary that CHs selected are uniformly distributed in network. Overhead changes in CHs and advertising, energy consumption is much.

b. Hybrid Energy-Efficient Distributed clustering (HEED) [14]:This protocol is multi-hop WSNs algorithm, and takes the energy value in consideration. As in LEACH it does not select the CHs randomly. It takes two parameter in consideration one is residual energy and second is intra-cluster communication cost. In HEED, CHs have the high residual energy then MNs. The main goal is CHs is evenly distributed. Here the Probability of a node becomes CH is:

$$CH_{prob} = C_{prob} \frac{E_{residual}}{E_{max}}$$

Where $E_{residual}$ is the estimated current energy of the node, and E_{max} is the reference maximum energy, C_{prob} is set to assume that an optimal percentage cannot be computed a priori. This is identical for all nodes in network [12]. HEED iteration is done for selecting CHs, two status that announcing for neighbors that the CH_{prob} is less than 1 then it is become tentative CH and if it is 1 then it become permanent CH. CHs send the data in multi-hop fashion.

The advantages of HEED is as it is fully distributed, it provide uniform distribution of CH in network and load balancing, multi-hop communication save energy of CHs and it may be work in large networks. It has some limitations that are tentative CHs leave some nodes uncovered, then these are become CHs that have no members, that the result is unbalanced energy consumption. In performing clustering is in round or iteration become overhead that it has to broadcast a lots of packets in network to decrease lifetime of network. So CHs that near the sink may die earlier.

***c. Distributed Weight-based Energy-efficient Hierarchical Clustering protocol (DWEHC*)**: proposed by ding et al.[15]. The main objective of DWEHC is to using location awareness of nodes to develop balanced cluster sizes and to make effective intra-cluster topology. DWEHC and HEED have some similarity that both have no considerationof network size, densityin election of CH of network size. DWEHC apply on every node individually and require number of iteration in distributed manner. DWEHC generates a multi-level structure for intra-cluster communication and generates parent node which is limited by the number of children. It calculates the parameter locally for CH node election. The nodes that have large weight would be selected as the CH and other areas member nodes. Here in intra-cluster member nodes move from 1-level to h-level the level one node lies near the CH and if MNs are far from CH that become h-level nodes.

For defining the level limits by the cluster range R within which MNs should lay. Communication is done by TDMA, The parent node communicate to direct children and forwards data to the parent before reaching to the CH. Advantages of the DWEHC is that it reserves energy during CH selection. DWEHC consumes low energy in intra-cluster and inter-cluster. Some demerits of DWEHC are that it's CHs directly communicateswith BS so not applicable for large-region networks. It produces high control message overhead relative other protocols.

***d. Unequal Clustering Size (UCS) model [16*]:** Was proposed by Soro and Heinzelman, dividing of the network in clusters utilize energy efficiently but unbalance energy consumption problem comes. In Heterogeneous clusters, cluster head nodes have to perform more powerful role in network that should be ensured balanced energy dissipation. In unequal clustering size (UCS) model network nodes can perform uniform energy dissipation between CHs, so that lifetime of network can increase. Here UCS applies in homogeneous network that can perform more energy dissipation. Here the heads position is predetermined in form of symmetric concentric circles in the region of base station. For the homogeneous and heterogeneous networks, The UCS gives the 10-30% over the Equal Clustering Size (ECS). It is depending on the how cluster head nodes aggregate data. It is better for large

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collection of data for the network. The limitation of the UCs is that its constraint that it assumes that the network is heterogeneous nodes are deployed pre determined location.

e. ***Algorithm for Cluster Establishment (ACE) [17]:***Presented by Chan and Perrig, ACE uses emergent algorithms, ACE has divided in two logical parts – first one is the creation of new cluster and in a cluster a node elect self a cluster head and the second is how cluster move dynamically to reduce overlap. In general, the new clusters are created when existing cluster is small in size. The new cluster is move a part for minimize mutual overlapping, it is done by the iteration. When new clusters are produced then nodes want to become cluster head then self-elective process started. It broadcast a RECRUIT message to its neighbors, who will be followers of the new cluster. Until the protocol is running a node can be the follower more than one cluster and choose any one cluster at the end of the protocol. Migration is controlled by cluster head of existing cluster. To determine the best candidate for leader of cluster, each cluster head sets a period of time and then sends the POLL to all its followers. The candidate will be selected as the cluster head if it would have greatest number of nodes as followers while minimizing the amount of overlap with existing cluster. The best candidate is PROMOTED as cluster head by current cluster head and ABDICATE itself as old cluster head. The old cluster head will not be the part of that cluster. ACE is an emerging algorithm that to forms uniform clusters over network as it uses three round feedback for highly efficient network. Some advantage are ACE is scale independent means it completes in time constant but does not care of size of network, it work on without use of geographic knowledge of node positions or distance or direction between nodes. It is scalable and robust new node can add into the network and repair itself by node selection if head is damaged. Limitation is that it not considered the important factor that is energy in election of head. How much iteration requires, it is hard to know for election CHs and generation of cluster. It requires much communication cost and energy consumption.

f. ***Base-Station Controlled Dynamic Clustering Protocol (BCDCP*)**: proposed by Murugathan et al.[18], is a centralized clustering routing protocol with the BS perform the complex computation. The main idea that the BS performs clustering, clusters are divided in equal number of MNs each cluster and the head is also uniformly divided throughout the network.

For the formation of the cluster, first setup the BS is done then the residual energy from whole network and check the average energy level set of node is received from whole network. It chooses the set of nodes which has the higher value than average that are selected as the CHs for the current round. While another node that has low energy value then for long life of by performing the task of ONs. Based on the chosen set, the BS figures the number of clusters and perform iterative cluster splitting algorithm for complete of task of clustering. Now the splitting algorithm performs sub clustering until the desired number of clusters are formed. At the each iteration network is divided in clusters, two node that have the maximum partition distance are selected as the CHs from chosen set which are eligible for CHs. Remaining node are work as the clusters nodes. Clusters are grouped as same number of nodes. BCDCP, multi-hop routing used to send data to the BS. Once the CHs are identified, then BS chose the lowest-energy path and it collects all information related to clusters and CHs. When it transfers the information the Minimum Spanning Tree (MST) [19] approach is used. Random shortest CH path are chosen to forward data to the BS. Advantages of the BCDCP are that BS constructs the cluster and transmission path. So that it resolved the problem of CH distribution ensures that all the CHs have the same energy is dissipation. TDMA is applying for the cluster members. This allows open communication interfaces if data transmission are required. Disadvantages in BCDCP is a centralized algorithm so scalability and robust for large network is worse than distributed algorithm. Design complexity increases due to each node have to transmit information about its location and energy level to the BS during cluster formation.

B. Data-Transmission Based Clustering Routing Protocols:

a. ***PEGASIS* :** Power-Efficient Gathering in Sensor Information Systems (PEGSIS), proposed by Lindsey et al.[20] The main idea of the PEGASIS is that nodes communicate to nearby neighbors and try to acquire leadership for transmission to the sink. In PEGASIS, distributions of node are randomly and distribution of energy load equally between the sensor nodes in the network.

In PEGASIS, is an lean-to of LEACH protocol, each sensor nodes received and transmit data from neighbor chain to the sink. The chain is creation is completed by greedy algorithm. The data are gathered and forward it to node to node, aggregated and send to base station. In PEGASIS creation stage it assumes that the sensor nodes have knowledge about the network's sensor position. Whenever any sensor node fails or battery down then it bypass the fail node and construct the chain again.

In each round the data are gathered by each sensor node and fused data its own that data are received by the one neighbor and at final reached to the sink by leader. In each round, a control token is passing this approach by leader to start data transmission at the end of chain. In following diagram it is shown that if S_1 is leader will pass the token to S_0 at first then S_0 pass the data to the S_1. After node S_1 received data from node S_0 it will pass the token to S_3 and it pass data to S_1 then fusion take placed and then data forward to the sink.

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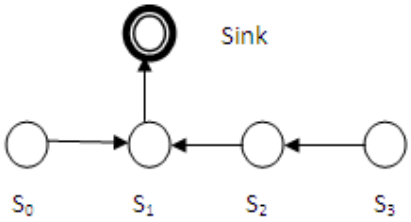

Some advantages of the PEGASIS firstly it can perform best than LEACH for different network sizes and topologies because it reduces formation of dynamic cluster in LEACH, and through the data chain data aggregation it decrease data transmission. Secondly energy load dispersed uniformly in the network.

The disadvantages of it is that it requires necessary information of whole network topology for chain construction and all node must be able to transmit directly to the sink. It is unsuitable for time varying topology. Other demerit that It believe that node can able to communicate directly, but in practically multi-hop communication is perform to the sink. For long range communication much energy consumption is performed. Another problem with it is that excessive delay due to chaining communication and suffer from bottleneck problem. It is difficult to manage huge amount of database about location of nodes in the network so problem in scaling of the network but it is better than the LEACH protocol.

V. CONCLUSION AND FUTURE WORK

WSN applications help both civilian and military people. One major challenge is to design an efficient routing strategy. A routing protocol should be energy efficient, load balancing, fault tolerant, scalable and should provide high level of security but still it is a challenging task. Many routing protocol have been developed for use in sensor network but most of them do not meet conditions of performance metric and QoS. One of the challenging task is to maintain the energy level in sensors. In this paper, we tried to cover some evaluation of metrics for routing protocol in wireless sensor network. Some cluster routing algorithms that meet some constraint and challenges are also discussed. Some important related research that may be carried out in future includes design routing protocols with managed duty cycled nodes. Actual design should concentrate on three-dimensional sensor fields. Energy constraint issue should also be considered for a longer lifetime.

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