A Review on Routing Protocols in Wireless Sensor Networks

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Abstract: *Advances in Wireless Sensor Network has led to large scale development.WSN technology has been provided with the ability of small nodes with sensing, computation ,and the wireless communication capabilities .In WSN ,a large number of constrained attached to the sensor nodes which have a limited transmission range ,less processing capability ,low storage capability ,and as well as their energy resources are also inadequate.*

In WSN ,the routing protocols are responsible for maintaining the routes in the network .It also ensures reliable multi-hop communication under these conditions .This paper gives a review on the routing protocols that are used in the WSN and compare their strengths and limitations.

Keywords: Wireless Sensor Networks, Challenges and Design Issues, Routing Protocols.

I .Introduction

WSN is widely considered as one of the most important technology in the twenty-first century[1].Over the past few years ,technological advancement in the design of processors , memory ,and radio technology have shown an active interest in the area of distributed micro-sensing ,in which a number of independent ,self-sustainable nodes combine to perform a large sensing task .Wireless sensor networks have applications in many important areas, such as the military ,homeland security, health care, the environment, agriculture, and manufacturing[3]. Wireless sensor network is an emerging field.WSN is becoming popular day by day.

A wireless network consists of tiny devices which monitors the physical or environmental conditions such as temperature, pressure, motion or pollutants etc. at different areas .

Due to the rigorous energy constraints of large number of densely deployed sensor nodes, it requires a suite of network protocols to implement various network control and management functions such as synchronization, node localization, and network security. The traditional routing protocols have several shortcomings when applied to WSNs, which are mainly due to the energy-constrained nature of such networks [4].

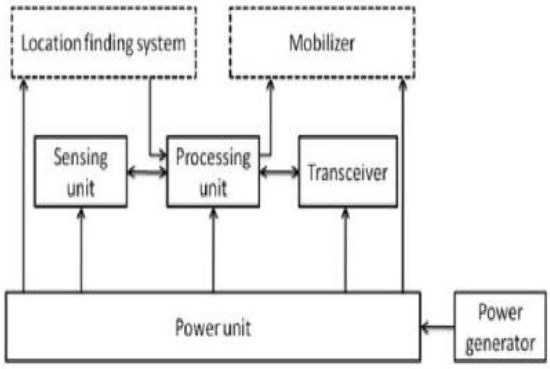

Fig.1 Sensor Node Component

Large number of research activities have been carried out to explore the constraints of WSNs and to solve the design and application issues. In this paper numerous routing protocols for wireless sensor network are discussed and compared. In Section 2,of the paper the network design challenges and routing issues are described. In Section 3, various routing protocols are discussed and compared. Finally, in Section 4 the conclusion is given.

II. Routing Challenges and Design Issues

In wireless sensor networks, the networking layer is mostly used to implement the routing of the incoming data. Routing can be defined as a process of determining a path between source and destination based upon the request of the data transmission. Routing algorithm uses the routing table along with the routing protocols for their construction and maintenance.

A.Routing Challenges and Design Issues

Depending upon the applications, different design goals and architectures have been considered for the sensor networks. Here we summarized some of the routing challenges and design issues that affect routing process in WSNs.

- *Node deployment*: Due to its application dependent nature it affects the performance of routing protocol. The deployment is either deterministic or self organizing. In deterministic, the data is routed through pre-determined path whereas in self-organizing the sensor nodes are scattered randomly creating an infrastructure in adhoc manner. Therefore, it is likely that a route will consist of multiple wireless hops.
- *Network dynamics*: Routing messages from or to the moving nodes is more challenging as the routing stability is an important issue. So, depending on the application the sensed event can be either dynamic or static.
- *Energy considerations*: Since the sensor nodes have limited energy capacity therefore energy poses a big challenge for the network designers. Thus, the routing protocols are designed for the sensors such that the sensors should be energy efficient due to which their lifetime is extended.
- *Data aggregation*: Similar packets from multiple nodes are aggregated to reduce the transmission. This technique is used to achieve the energy efficiency. It is a combination of data by using different functions such as suppression, min, max and average.
- *Sensor Locations*: As it is difficult to manage the location of the sensors hence it is also an important designing issue. The routing protocol includes a protocol which assumes that the sensors are equipped with global positioning system.
- *Data Reporting Model*: In WSN, Data sensing and data reporting is dependent on the application and time criticality of the data reporting .The categorization of data reporting can be done as time-drive , event-driven, query-driven, and hybrid. The routing protocol is highly influenced by this model in term of energy consumption and route stability.

III. Routing Protocols in Wireless Sensor Networks

In WSN the routing protocols are classified in four ways according to the way of routing path established, network structure, protocol operation and lastly by the initiator of communications.Fig.2 shows the classification of the routing protocols in WSN.

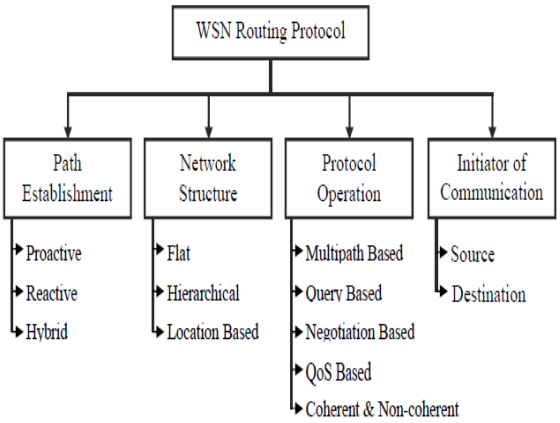

Fig.2 Classification of Routing Protocols in WSNA

Routing protocol is considered adaptive if certain parameters can be controlled in order to adapt the current network conditions and available energy levels. The routing in WSN is differ from conventional routing in fixed network in different ways as there is no infrastructure, wireless links are unreliable, sensor nodes may fail and routing protocols have to meet the exacting energy

requirements. All major routing protocols proposed for WSN may be divided into seven categories as shown in table.

Table 1. Routing Protocols for WSNs

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-Directed Routing, 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-1 Multipath Discovery
Heterogeneity-based Protocols	IDSQ, CADR, CHR
QoS-based protocols	SAR, SPEED, Energy-aware routing

3.1 Location-Based Protocols

In this routing, the sensor nodes are addressed by means of their location. To calculate the distance between two neighbouring nodes can be estimated on the basis of incoming signal strengths. To save energy, some of the location based schemes are demanded such that the nodes should go to sleep if there is no activity.

3.1.1Geographic Adaptive Fidelity (GAF)

GAF is an energy aware location based routing protocol used for MANET but also applicable for sensor networks.GAF can be implemented for mobility and non-mobility of nodes.GAF can substantially increases the network lifetime as the number of nodes increases. There are three states which are defined in GAF are is to determine the neighbours in the grid, active reflecting participation in routing and sleep when the radio is turned off.GAF conserves the energy by turning off unnecessary nodes in the network without affecting the level of routing fidelity.

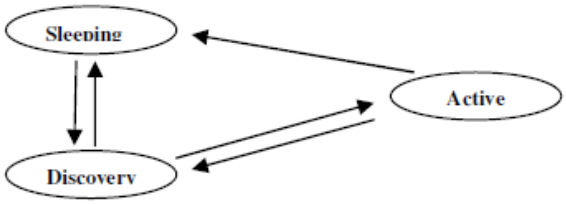

Fig.3 State transition diagram of GAF

3.1.2 Geographic and Energy-Aware Routing (GEAR)

GEAR uses the energy aware and geographically-informed selections to route a packet towards the destination region. GEAR uses a recursive geographic forwarding algorithm to disseminate the packet inside the target region.

3.1.3 SPAN

This protocol selects some nodes as coordinators that are based on their positions .The network backbone forwards the messages by using the coordinators. SPAN does not require that the sensors should know about their location information as it runs properly with the geographic forwarding protocol.

3.1.4 Trajectory-Based Forwarding (TBF)

TBF routing protocol requires a adequately dense network and the presence of coordinate system. The route maintenance in TBF is untouched by sensor mobility given that a source route is a trajectory that does not include the name of the forwarding sensors. It can also be used for the resource discovery.

3.1.5 Bounded Voronoi Greedy Forwarding (BVGF)

In the BVGF routing protocol the sensors should be aware of their geographical positions(by the concept of Voronoi diagram).The BVGF protocol chooses as the next hop the neighbour that has the shortest Euclidean distance to the destination surrounded by all the eligible neighbours. BVGF does not regard energy as a metric.

3.1.6Geographic Random Forwarding (GeRaF)

Geographic random forwarding routing protocol is also known as best-effort forwarding. This routing protocol assumes that all the sensors are aware of their physical location and of the sink also. The sensors do not keep the track of the locations of their neighbours and the awake-sleep schedules.

3.1.7 Minimum Energy Communication Network (MECN)

MECN routing protocol was introduced for achieving minimum energy for randomly deployed ad hoc networks, which maintain a minimum energy network with mobile sensors .MECN is a self-reconfiguring protocol, it suffers from severe battery depletion problem .To address this problem ,MECN constructs an sparse graph and thus the minimum power topology should be dynamic based on the residual energy of the sensors.

3.1.8 Small Minimum-Energy Communication Network (SMECN)

To improve MENC, SMECN routing protocol is proposed. In SMECN routing protocol, every sensor discovers its instantaneous neighbours by broadcasting a neighbour discovery message using some initial power that is updated incrementally.

3.2 Flat Routing

Flat routing is also known as *data centric* routing. Due to the large number of nodes it is not feasible to assign a global identifier to each node. In data-centric protocols, when the source sensors send their data to the sink then the intermediate sensors can perform some form of aggregation on the data originating from multiple source sensors and then send that aggregated data towards the sink. Some of the data centric routing protocols are described below.

3.2.1 Sensor Protocols for Information via Negotiation (SPIN)

SPIN protocols are resource aware and resource adaptive. The family of SPIN protocol uses data negotiation and resource-adaptive algorithms. The energy consumption is computed by the sensors which are running the SPIN protocol. Key mechanism used by SPIN protocol is negotiation and resource adaptation.

3.2.2 Directed Diffusion

It is a protocol that is used for the sensor query dissemination and processing. The key elements used are data naming, interests and gradients, data propagation and reinforcement. At the beginning of the process, the sink specifies the low data rate for incoming events after that the sink reinforces one particular sensor to send events with a higher data rate by resending the original interest message with a small interval.

3.2.3 Rumor Routing

This routing is a compromise between the query flooding and event flooding app schemes. Rumor routing is based on the concept of an agent, agents travel the network in order to propagate information about local events to distant nodes.This routing maintains only one path between the source and destination.

3.2.4 COUGAR

This routing protocol is a database approach to tasking sensor networks. COUGAR uses a query layer where every sensor is associated with a query proxy that lies between the network layer and the application layer of the sensor. Query proxy provides the higher level services through queries that can be issued from a gateway node. This is used to reduce the total energy consumption and enhance the network lifetime.

3.2.5 Active Query Forwarding in Sensor Networks (ACQUIRE)

ACQUIRE mechanism is used for querying named data. It provides query optimization to answer specific types of queries that are called as one-shot complex queries for replicated data .ACQUIRE allows sensor to inject an active query in a network following either a random or a specified trajectory until the query get answered by some sensors on the path using a localized update mechanism.

3.2.6 Energy-Aware Data-Centric Routing (EAD)

EAD is a novel distributed routing protocol which build a virtual backbone composed of active sensors that are responsible for in-network data processing and traffic relying.EAD approach is energy aware and help to extend the network lifetime. The gateway plays the role of a data sink or event sink where each sensor acts as a data source.

3.3 Hierarchical Protocols

Hierarchical routing works in two layers, first layer is used to choose cluster heads and the other layer is used for routing. To make the WSN more energy efficient, clusters are created and special tasks (data aggregation, fusion) are assigned to them. It increases the overall system scalability, lifetime, and energy efficiency.

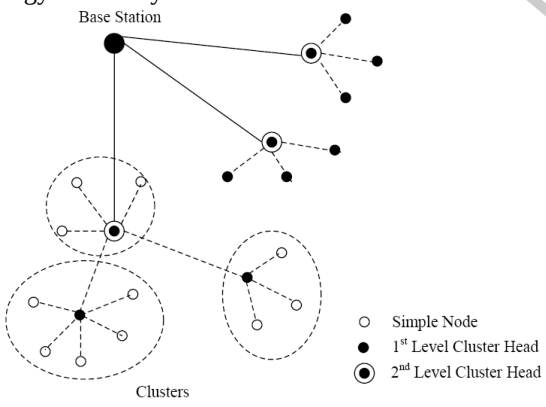

Fig.4 Cluster-based Hierarchical Model

3.3.1Low-energy adaptive clustering hierarchy (LEACH)

In LEACH, the clustering task is rotated between the nodes, based on duration. LEACH is based on an *aggregation* (or *fusion)* technique that aggregates the novel data into a smaller size of data that carry only coherent information to all individual sensors. LEACH is completely distributed and requires no global knowledge of network. LEACH uses single-hop routing where each node can transmit directly to the cluster-head and the sink.

3.3.2 Power-Efficient Gathering in Sensor Information Systems (PEGASIS)

PEGASIS is an extension of the LEACH , which forms chains from sensor nodes so that each node transmits and receives from a neighbour and only one node is selected from that chain to transmit to the sink. In PEGASIS routing protocol, the creation phase assumes that all the sensors have global knowledge about the network, mainly, the positions of the sensors, and use a greedy approach. When a sensor fails or dies due to low battery power, the chain is constructed by using the same greedy approach by bypassing the failed sensor. PEGASIS still requires dynamic topology adjustment since a sensor node needs to know about energy status of its neighbours in order to know where to route its data.

3.3.3 Hybrid, Energy-Efficient Distributed Clustering(HEED)

It operates in multi-hop networks, using an adaptive Transmission power in the inter-clustering communication. HEED was proposed with four primary goals namely (i) prolong network lifetime by distributing energy consumption, (ii) terminating the clustering process within a constant number of iterations, (iii) minimizing control overhead, and (iv) producing well-distributed CHs and compact clusters. Though, the cluster selection deals with only a subset of parameters, which can possibly impose constraints on the system.

3.3.4Threshold Sensitive Energy Efficient Sensor Network Protocol(TEEN)

TEEN is a hierarchical clustering protocol, which groups sensors into clusters with each led by a CH. The sensor network architecture in TEEN is based on a hierarchical grouping where closer nodes form clusters and process goes on the second level until the BS (sink) is reached. TEEN uses a data-centric method with hierarchical approach. Important features of TEEN include its suitability for time critical sensing applications. TEEN is not suitable for sensing applications where periodic reports are needed since the user may not get any data at all if the thresholds are not reached.

3.3.5Adaptive Periodic Threshold Sensitive Energy Efficient Sensor Network Protocol (APTEEN)

APTEEN is a hybrid clustering-based routing protocol that allows the sensor to send their sensed data regularly and react to any sudden change in the value of the sensed attribute by reporting the corresponding values to their CHs. APTEEN supports three different query types namely (i) historical query, to analyze past data values, (ii) one-time query, to take a snapshot view of the network; and (iii) persistent queries, to monitor an event for a period of time. APTEEN guarantees lower energy dissipation and a larger number of sensors alive.

3.4 Mobility-based Protocols

Mobility is a new challenge to routing protocols in WSNs. Sink mobility requires energy efficient protocols to guarantee the data delivery originated from source sensors towards the mobile sinks. In this section we discuss some of the mobility-based routing protocols for mobile WSNs.

3.4.1Joint Mobility and routing Protocol

A network with a static sink suffers from a severe problem, called energy sink-hole problem, where the sensors located around the static sink are used for forwarding data to the sink on behalf of other sensors. To address this problem, a mobile sink forgathering sensed data from source sensors was suggested. The optimum mobility strategy of the sink is a symmetric strategy in which the trajectory of the sink is the periphery of the network. The trajectory with a radius equal to the radius of the sensor field maximizes the distance from the sink to the centre of the network that represents the hot spot.

3.4.2 Data MULES Based Protocol

Data MULE bases protocol was proposed to address the need of guaranteeing the cost-effective connectivity in a sparse network while reducing the energy consumption of the sensors. It is a three-tier architecture based on mobile entities, called mobile ubiquitous LAN extensions (MULE).MULE architecture is fault tolerant and very robustness and scalable.

3.4.3 Scalable Energy-Efficient Asynchronous Dissemination (SEAD)

SEAD is self-organizing protocol, proposed to trade-off between minimizing the forwarding delay to a mobile sink and energy savings. SEAD consists of three main components namely dissemination tree *(d-tree)* construction, data dissemination, and maintaining linkages to mobile sinks. SEAD can be viewed as an overlay network that sits on top of a location-aware routing protocol, for example, geographical forwarding.

3.4.4 Dynamic Proxy Tree-Based Data Dissemination

This was proposed for maintaining a tree connecting a source sensor to multiple sinks that are interested in the source. This helps the source disseminate its data directly to those mobile sinks. In this framework, a network is composed of stationary sensors and several mobile hosts, called *sinks.* The sensors are used to detect and continuously monitor some mobile targets, whereas the mobile sinks are used to collect data from precise sensors, called *sources*, which may detect the target and regularly generate detected data or aggregate detected data from a subset of sensors.

3.5 Multipath-Based Protocols

Multiple paths are used to increase the network performance. When the primary path fails between the source and the destination an alternate path exists that measure the fault tolerance of a protocol. This can be enlarged, by maintaining multiple paths between the source and the destination. This increases the cost of energy consumption and traffic generation. The alternate paths are kept alive by sending periodic messages. Due to this, network reliability can be increased. Also the overhead of maintaining the alternate paths increases.

3.6 Query Based Routing

In this kind of routing, the destination nodes propagate a query for data (sensing task) from a node through the network and a node having this data sends the data which matches the query back to the node, which initiates the query. Usually these queries are described in natural language, or in high-level query languages.

3.7Negotiation Based Routing Protocol

In order to eliminate redundant data transmissions, this protocol use high level data descriptors through negotiation. Based on the resources that are available to them communication decisions are taken. The motivation is that the use of flooding to disseminate data will produce implosion and overlap between the sent data; hence nodes will receive duplicate copies of the same data. This consumes more energy and more processing by sending the same data to different sensor nodes. Hence, the main idea of negotiation based routing in WSNs is to suppress duplicate information and prevent redundant data from being sent to the next sensor node or the base-station by conducting a series of negotiation messages before the real data transmission begins.

3.8 QoS-based Protocols

To minimize energy consumption, quality of service requirements is considered to be important in terms of delay, reliability, and fault tolerance in routing in WSNs. In this section, we review a sample QoS based routing protocols that help find a balance between energy consumption and QoS requirements.

3.8.1 Sequential Assignment Routing (SAR)

Routing decision in SAR is dependent on three factors: energy resources, QoS on each path, and the priority level of each packet. The objective of SAR algorithm is to minimize the average weighted QoS metric throughout the lifetime of the network. SAR maintains multiple paths from nodes to BS. Although, this ensures fault-tolerance and easy recovery, the protocol suffers from the overhead of maintaining the tables and states at each sensor node especially when the number of nodes is huge.

3.8.2 SPEED

This QoS routing protocol provides soft realtime end-to-end guarantees. This protocol requires each node to maintain information about its neighbours and uses geographic forwarding to find the paths .The routing module in SPEED is called Stateless Geographic Non-Deterministic forwarding (SNFG) and works with four other modules at the network layer. SPEED performs better in terms of end-to-end delay and miss ratio

3.8.3 Energy-Aware QoS Routing Protocol

In this QoS aware protocol, real time traffic is generated by imaging sensors. The proposed protocol extends the routing approach and finds a least cost and energy efficient path that meets certain end-to-end delay during the connection. The link cost used is a function that captures the nodes' energy reserve, transmission energy, error rate and other communication parameters.

IV. Conclusion and Future Research

One of the main challenge in the design of routing protocols for WSNs is their energy efficiency due to the inadequate energy resources of sensors. The objective behind the routing protocols design is to keep the sensors operating for as long as possible. Therefore, routing protocols designed for WSNs should be as energy efficient to prolong the lifetime of individual sensors, and the network lifetime. In this paper, we have reviewed a sample of routing protocols by considering several classification criteria. The related research directions should receive attention from the researcher namely the design of routing protocols for duty-cycled WSNs, and three-dimensional (3D) sensor fields while designing such protocols.

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