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STUDY OF WIRELESS SENSOR NETWORKS

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Abstract:
Wireless Sensor Networks (WSN), consist of thousands or even more sensor nodes deployed either inside the phenomenon or very close to it depending upon the application. These sensor nodes are capable of sensing, actuating, and relaying the collected data, which have made a remarkable impact globally. The collected data by the sensing device must be gathered and transmitted to a base station where it is again processed for further end-user queries. Since the network consists of low-cost nodes with limited battery power, power management must be implemented for data gathering and processing in order to achieve long network lifetimes. Researchers are making their effort in developing new protocols for data transmission by the sensing devices in the network by keeping in mind the power efficiency and its management. The attention in these protocols is specifically given to routing protocols as they might differ based on the application and network architecture. As wireless sensor technology is refining itself a wide number of organizations are using it for a many range of purposes. This paper presents the complete overview about the Wireless Sensor Network including its architecture, hardware constraints and how this sensor works on network layer protocol. Network layer routing protocols are also described and discussed under the appropriate category. Moreover, protocols using contemporary methodologies such as network flow and quality of service modelling are also discussed.

Keywords: *WSN; Energy Efficient Routing; Fault Tolerance; Low Cost.*

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1. Introduction

With the advancement in network technology the growth of wireless communication and electronics have enabled the development of low-cost, low-power, multifunctional sensor nodes which are though small in size but makes communication possible at short as well as for long distances.

A sensor network consists of number of sensor nodes which are densely deployed either inside the phenomenon or very close to it. A single sensor node consist of sensing, data processing, communication components, which are combined together to give the idea of the sensor network.

We don't need to predetermine the position of any of the sensor nodes in the network. Random deployment occurs in the network of the nodes which also means that self-organising capabilities

must be shown by the sensor network protocols and the algorithms. Another interesting feature of WSNs is that the sensor nodes cooperate with each other. An in-built processor in the sensor nodes helps in processing raw data before transmitting it. The ambient conditions are sensed by the sensing circuitry and transform that into an electrical signal. Some properties about objects located and/or events happening in the vicinity of the sensor are revelled by processing such signals. The collected data is than send by sensor via radio transmitter to a command sender either directly or by data concentration centre.

After the realization of the wide range applications of the sensor network, it requires wireless ad-hoc networking techniques. Since many protocols and the applications were proposed for the traditional wireless ad-hoc networks, but were not well suited to the requirements of the sensor networks. Let's see the difference between the sensor network and the ad-hoc network to illustrate the above mentioned point:

- Sensor nodes are densely deployed into the network.
- The nodes in the ad-hoc network are fewer than the number of sensor nodes in the sensor network which can be of several orders of magnitude.
- Sensor nodes are prone to failure.
- The topology of the sensor networks changes rapidly due exhausting battery life of the nodes.
- Broadcast communication paradigm is mainly used in the Sensor nodes whereas ad-hoc networks are based on the point-to-point communication.
- Sensor nodes in WSN uses limited power, computational capacities and memory.

Many-a-times sensor network doesn't have global identification (ID) because of the vast number of overhead and the sensor in the network.

To fulfil the requirements many researchers are working in this area to develop the schemes.
In this paper we are presenting the survey on Wireless Sensor Networks. Our aim is to provide the better understanding of the WSNs architecture, its hardware constraints and how this sensor works on the network layer protocol.

We also attempt to describe and discuss the network layer routing protocols under the appropriate categories.

2. Sensor Networks Communication Architecture

All the sensor nodes are scattered in the sensor field as shown in the figure 1. Each of these sensor nodes has capability to collect the data and route back to the sink as shown in the diagram. Data are routed back to the sink by a multihop infrastructure less architecture through the sink. Finally the transmitted data by the nodes in the form of electric signals are collected by the task manager node (User node). But the design shown in Figure 1 is influenced by many factors, including the fault tolerance, scalability, and production cost, hardware constraints, operating environment, sensor network topology, transmission media and power consumption.

2.1. Design Factors

Several design factors were shown by researchers as surveyed in this paper. However fully integrated view of all the factors driving the design of the sensor networks or sensor nodes are not given by any of the studies. We are studying these design factors because they are very important as they serve as a guideline to design a protocol or an algorithm for sensor networks.

Fault Tolerance- Sometimes due to lack of power supply, environmental issues or some physical damages may result in the failure of the sensor nodes. This failure of sensor node should not affect the overall performance of the sensor network. This is the reliability or the fault tolerance issue. We can say that the fault tolerance is the ability to sustain the sensor network working and functionalities without any interruption due to any failure in any of the sensor nodes [1, 2].

Scalability- In a sensor network there may be hundreds or thousands of sensor nodes deployed for the study of the phenomenon. These numbers can increase to millions depending upon the application used. Scalability says that new schemes must be able to work with these increasing numbers of nodes.

Production Cost- In any sensor network large number of the sensor nodes are deployed. Therefore the cost of a single node must be justified so that the overall cost of the sensor network can be analysed. If this cost is exceeding the cost of the traditional sensors then it is not justified cost. The cost should be kept low of each sensor nodes.

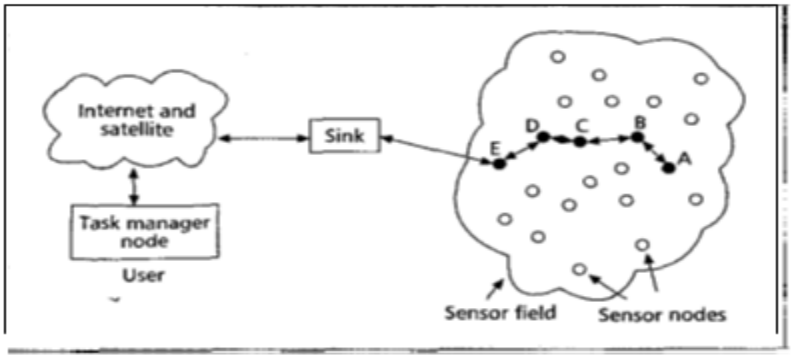

Figure 1: Sensor nodes scattered on a sensor field

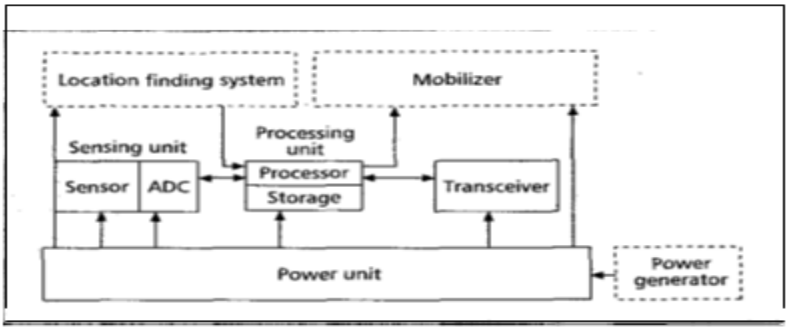

Figure 2: Components of a sensor node (hardware constraints)

Hardware Constraints- As shown in figure 2, a sensor node consists of four basic components. The components of the sensor nodes are: *a sensing unit, a processing unit, a transceiver unit* and *a power unit*. It also has some additional application-dependent components as shown in the figure 2: *location finding system, power generator* and *mobilizer*.

1) A *sensing unit* are usually composed of two subunits: sensors and analog-to-digital converter (ADCs). Various ambient conditions are sensed by the nodes in analog form and are converted to digital form by ADCs and transmitted further to the processing unit.
2) The *processing unit* collects the data or information from the sensing unit and manages all the procedure that collaborates the sensor nodes to work with one another to carry out the assigned task.
3) A *transceiver unit* connects the nodes to the network.
4) The *power unit* is one of the most important component of any sensor's hardware. It may be supported by the other power scavenging. Knowledge of the location is required by the sensing network routing technique. Therefore, location finding system is common to be as one of the unit of the hardware constraints of sensing network. When it is required to carry out the assigned tasks to move the sensor network mobilize may require.

A match box sized module [3] of even less than cubic centimetre [4] is used to fit these subunits discussed, Because of its light weight this module can be suspended in the air. Beyond this a sensor node must consume extremely low power should have low production cost, operate in high volumetric densities, be dispensable and autonomous, and be adaptive to the environment [5].

Operating Environment- A sensor network consists of number of sensor nodes which are densely deployed either inside the phenomenon or very close to it. Therefore, they usually work unattended in remote geographic areas. They may be working in the interior of the large machines, at the bottom of the ocean, in the biogeographically and chemically contaminated field, and in a home or large buildings.

Social Network Topology- Hundreds to thousands number of sensor nodes are deployed within any sensor network. Careful handling of topology maintenance is required for deploying a high number of nodes.

Transmission Media- Depending on the application of the sensor network, the data delivery model to the sink can be continuous, event-driven, query-driven and hybrid[6]. In the continuous delivery model, each sensor sends data periodically. When any event occurs or any query is generated by the sink the transmission of the data is triggered in event-driven and query driven models. Some networks apply a hybrid model using a combination of continuous, event-driven and query-driven data delivery. In a multihopsensor network, communicating nodes are linked by a wireless medium. This link can be formed by either radio, infrared or by the optical medium. The chosen medium must be available worldwide to enable global operation of this network.

Power Consumption- For topology management and medium access control multi-hop routing introduces significant overhead. If all the nodes were very close to the sink [7] direct routing would perform well enough. Since wireless sensor node is a microelectronic device, can only be

equipped with a limited power source. In some applications scenarios, replenishment of power resources might be impossible. Therefore it shows a strong dependence on battery lifetime. Power consumption and power management plays a very important role as the malfunctioning of a new node may cause significant topological changes and might require rerouting of packets and reorganization of the networks. This is the reason why the researchers are focusing on the design of power aware algorithm and the protocols for sensor networks.

3. Routing Protocol for WSNs

We need special multihop wireless routing protocols between the sink node and the sensor node because of the fact that the sensor nodes are scattered either close enough or inside the phenomenon as we also discussed before. All the requirements are not fulfilled by the traditional ad-hoc routing technique of the sensor networks because of the reason explained earlier. The design of the networking layer of the sensor network is done with the following mentioned principles:

- Power management plays a vital role.
- Mostly the sensor networks are data-centric.
- Attribute based location and addressing awareness describes an ideal sensor networks.

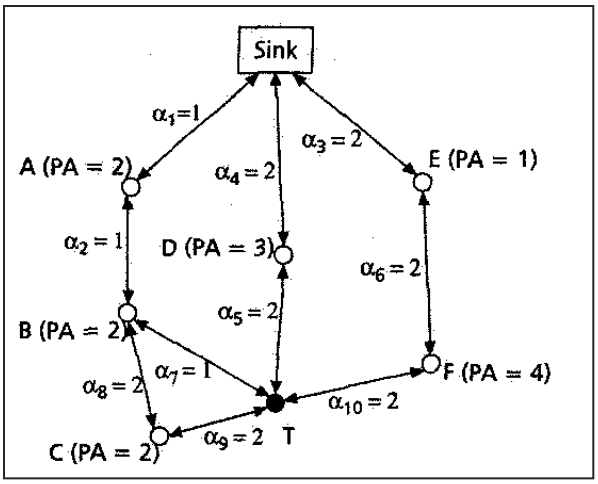

Figure 3: The power efficiency of the routes.

On the basis of the available power (PA) in the nodes the energy efficient routes can be formed for the transmission in the links along the routes.

In figure 3, node T is the source node that senses the activity or the phenomenon. For the communication with the sink it has following possible routes:

- Route 1: Sink-A-B-T, total PA = 4, total $\alpha = 3$.
- Route 2: Sink-A-B-C-T, total PA = 6, total $\alpha = 6$
- Route 3: Sink-D-T, total PA = 3, total $\alpha = 4$
- Route 4: Sink-E-F-T, total PA = 5, total

$\alpha = 6$

One of the following approaches is selected for an energy efficient route:

Maximum PA route: By summing all the PAs of each node along with the route total PA is calculated. That route will be preferred which will have the maximum value of the PA. From figure 3, based on this approach route 2 is preferred. But since route 2 includes the nodes in route 1 and an extra node. Although route 2 has highest total PA but it is not power efficient. Therefore don't consider route 2 and eliminate it. Now we will select route 4 as it has highest total PA.

Minimum energy (ME) route: While sending the data packets between the sink and the sensor nodes the route that consumes minimum energy is selected and known as ME route.
In figure 3, route 1 is selected as ME route.

Minimum Hop (MH) route: While reaching the sink the route that makes minimum hop is preferred and known as the MH route. In figure 3, route 1 is preferred based on this scheme. Note that MH and the ME scheme will select the same route whenever the same amount of energy will be provided to every link. Therefore, whenever without power control the nodes are broadcasted with same power level ME will be equivalent to the MH.

Maximum minimum PA node route: In this scheme that route is preferred for which the route is having the minimum PA which is larger than that of the minimum PA(s) of the other routes. In figure 3, the route 3 is preferred as it is the most efficient.

Routing is based on the data centric approach which is another important issue. To assign the sensing tasks to node for interest dissemination two approaches are preferred in this routing and that are: sinks broadcast the interest [3], and sensor nodes broadcast an advertisement for the available data [8] and wait for a request from the interested nodes.

In data centric routing the problem of overlap problems and the implosion is solved using data aggregation technique.

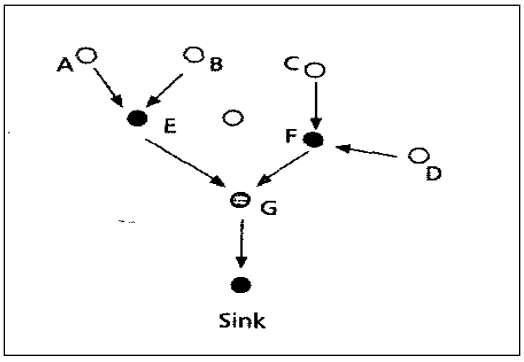

Figure 4: An example of data aggregation

Data aggregation is a set of automated data that comes from various sensor nodes and are combined to a set of meaningful information [9]. It is also known as data fusion [8].

Different scheme proposed to insight into current research on network layer for sensor networks are discussed in this section.

Soft Computing Techniques for WSN Routing

It has been observed that soft computing techniques and hybridized Genetic Algorithm has considerably improved the routing optimization. A simple approach to minimize the average path length is proposed in [10] where they considered the wireless network of sensor nodes having known spatial distribution using a GA approach. GAs for finding energy efficient shortest route for WSNs is emerging as an important field. The routing in WSN is a combinatorial optimization problem, hence GA can provide optimized solution to energy efficient shortest path. Evolutionary computing has been extensively applied to wireless sensor networks. Elitist GA is used that have inherent advantage whereby it keeps the elite solutions in the next generation so as to quickly converge towards the global optima. Considering the distance between the transmitter and receiver and the remaining energy of the nodes to find the energy efficient route is a better approach. Alternate node selection from the neighborhood is used along with hybrid GA so that the nodes do not deplete of energy and the network lifetime is extended [10].

Small Minimum Energy Communication Network

A protocol is developed in [11], that when a communication network is given, it computes energy efficient sub-network known as minimum energy communication network (MECN). After that another sub-network is proposed by [12] to provide such a sub-network popularly known as small minimum energy communication network (SMECN). SMECN follows the minimum energy property [13].

Flooding

Routing in the sensor network is done with the help of this technique. In this technique each node receives the data packets, unless maximum number of hops for the data packet is received or node itself be the destination of the packet. Flooding technique doesn't require any costly topology maintenance or any complex algorithm for route discovery because it is a reactive technique.

Gossiping

Gossiping is a derivation of the flooding technique. In this technique random selection of the neighbour occurs by the sensor node for sending the data packets. Once the data is send, another neighbour is again randomly selected and the process goes on unless the message is received. By having copy of the message at any node this technique avoids the implosion problem.

Sensor Protocol for Information Via Negotiation (Spin)

This is a family of adaptive protocols and is designed to address the deficiencies of classic flooding. It is designed based on two basic ideas: efficient operation of sensor nodes and energy conservation.

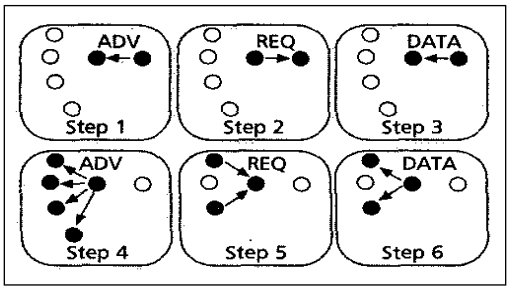

Figure 5: The SPIN protocol

This protocol is based on data centric routing [8] where the interested sinks sends the available data to already waiting sensor nodes.

Sequential Assignment Routing

This is a protocol that performs organization, management and mobility management operations in sensor nodes. It enables collection of sensor nodes and establishes the transmission schedule without involvement of any central management system to discover their neighbour. It is a distributed protocol. In this technique for routing the data back to the sink each sensor nodes select its own path. This selection process of path is based on the energy resources and the additive QoS metric of each path.

Low Energy Adaptive Clustering Hierarchy (Leach)

This protocol is based on clustering in sensor network it minimizes the energy dissipation. Clusterheads are selected in response of randomly selection of the sensor nodes by LEACH. Two phases are their which separates the operation of LEACH the setup phase and the steady phase. Setup phase select clusterheads and it is sensed by the sensor node. Once sensor node receives the advertisement, determination of the cluster occurs to which they want to belong.

The sensing and transmission of cluster heads occur at steady phase. Cluster head aggregate data from the nodes before sending to the base station.

Directed Diffusion

This protocol is proposed in [3], description of the task is send to all sensors by the sink as shown in figure 6. Cache of sensor node stores the description task (i.e. interest) which contains the time stamp field and several gradient fields.

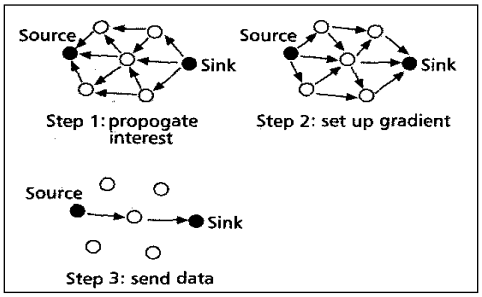

Figure 6: An example of directed diffusion.

When sink starts to receive data from the source the interest must be refreshed and reinforced. This approach is based on the data centric routing.

4. Conclusions

For remote sensing many new and exciting application area are created by sensor network having characteristics like flexibility, fault tolerance, low cost, and rapid deployment. Power saving is very critical to wireless sensor networks as the sensor nodes have limited battery life. Therefore while developing the protocols for WSN this aspect should be considered. From the study of various protocols it can easily understood that the maximum available power route, minimum

energy route, minimum hop route, maximum minimum power available route are some of the techniques which can be used for power routing in WSN. Some protocols also use data aggregation, residual energy of sensor nodes, minimum hop routing techniques for saving power. Sensor network is going to be an integral part of our lives in the future with wide range of application areas.

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