WIRELESS SENSOR NETWORKS: A SURVEY

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Abstract
Variety of fields which includes military, healthcare, environmental, biological, home and other commercial applications are using Wireless Sensor .Wireless Sensor Networks (WSN), which are made of several of sensor nodes that can sense, actuate, and relaying the collected information, have made remarkable impact everywhere due to vast advancement in the field of embedded computer and sensor technology. It is a group of small sensor nodes which communicate through radio interface. The four basic units viz: sensing, computation, communication and power are the essential part of any sensor nodes. The main characteristics of any sensor nodes are limited energy, communication capability, storage and bandwidth, which is also important for study point of view. Survey done in this research paper is on the basis of various aspects of wireless sensor networks. In this paper we also discussed various types of WSNs, their applications and try to through light on various categories of routing protocols.
Keywords: WSN, Sensor nodes, Applications, Sensor Networks types, Routing Protocols.

I. INTRODUCTION

A wireless sensor network [1][2] is defined as a collection of a large number of tiny low power, low cost and multi-functional sensor nodes which are randomly and highly distributed either within the system or extremely close to it. Sensor nodes which are very small in size consist of a sensing unit, data processing unit, and geographic positioning system, power supply unit such as battery or solar cell and communicating components such as radio systems. We can get position of the node using GPS, this not only gives random placement but also means that protocols of sensor networks and its algorithms should be able to acquire self organizing abilities in inaccessible areas.

Figure 1 is a basic block diagram of sensor node comprises five main components-

Controller A controller to process all the relevant data, capable of executing arbitrary code.

Memory Usually, different types of memory are used for programs and data. Some memory are used to store programs and intermediate data

Sensors and actuators The actual interface to the physical world: devices that can observe or control physical parameters of the environment.

Communication Turning nodes into a network requires a device for sending and receiving information over a wireless channel.

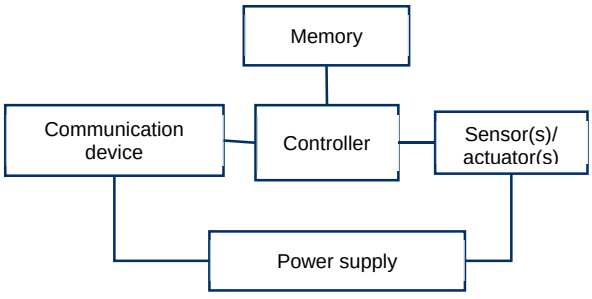

fig.1: Overview of main sensor node hardware components

II. TYPES OF WIRELESS SENSOR NETWORKS

With reference to research done in the past by various researcher, five types of wireless sensor networks are possible depending upon how these sensors are installed to monitor data. According to these properties of sensor deployment we can categorize WSNs viz; ground (terrestrial) WSN,

underground WSN, aquatic (underwater) WSN, multi-media WSN, and mobile WSNs.

A. Ground (Terrestrial) WSNs [11]
It consist of hundreds to thousands of inexpensive wireless sensor nodes deployed arbitrarily in a given sensing area. In ad hoc deployment, sensor nodes can be dropped from a surface area and arbitrarily placed into the target area. In a ground (terrestrial) WSN [11], reliable communication in a dense environment is very significant. Ground (Terrestrial) sensor nodes must be able to effectively communicate data back to the base station. Though battery power is limited energy resource and it is main constrain on network performance and due to which it may not be replaceable or rechargeable again, ground(terrestrial) sensor nodes however can be equipped with a secondary power source such as battery or solar cell. It is always important for sensor nodes to conserve energy. For a ground (terrestrial) WSN, energy can be preserved with short transmission range, multi-hop routing, eliminating data purity, in-network data aggregation, minimizing delays, and using low duty-cyclic operations.

B. Underground WSNs [11] are compilation of a number of sensor nodes positioned inside crust of earth or in a cave or in a mine and they are used to observe underground events such as volcanic conditions etc. Extra sink or base station nodes are located above crust of earth to transmit information from the sensor nodes to the sink(base station). These type of WSN are much more costly than a ground (terrestrial) WSN in terms of deployment, equipment, and maintenance. Underground sensor nodes are more expensive because it is important to select the necessary equipment in order to ensure reliable communication through rocks, soil, water, and other contents residing inside crust. The internal conditions environment makes wireless communication a challenge due to high levels of attenuation and signal losses.

Unlike ground WSNs [11], the deployment of an underground WSN needs precise planning and energy and cost considerations. Energy is an important constraint in underground WSNs. Like ground (terrestrial) WSN, underground sensor nodes are prepared with a limited battery power source and once deployed into the crust or ground, it is difficult to recharge or replace a sensor node's battery.

C. Aquatic (Underwater) WSNs [11] is a set of a number of sensor nodes and vehicles deployed inside water. As opposite to ground (terrestrial) WSNs, aquatic (underwater) sensor nodes are more costly and due to which a few sensor nodes are deployed in sensing region. Autonomous aquatic (underwater) vehicles are used for investigation or collecting of data from sensor nodes. As compared to a dense deployment of sensor nodes in a ground WSN, a sparse deployment of sensor nodes is placed at sea level (underwater). Typical aquatic (underwater) wireless communications are implemented through transmission of acoustic waves.

D. Multi-media WSNs [11] are set of various low cost sensor nodes guided with microphones and cameras. These sensor nodes interconnected with each other using a wireless connection for data sensing, data processing, data correlation, and data compression. Multi-media WSNs are used to allow observing and tracking of events in the form of multimedia applications.

E. Mobile WSNs [11] are of a set of moving sensor with their interaction with sensing environment. Moving sensor nodes are capable enough to sense, compute, and communicate like non-moving nodes. Mobile WSNs are used in military and other industrial applications.

III.SENSOR NETWORK ARCHITECTURE DESIGN

A Wireless sensor network [1][2] is defined as a network of various tiny cheap, disposable, low power devices, called sensor nodes, which are randomly distributed in order to perform their selected tasks such as fire sensing, weather monitoring etc. These sensor nodes form a network by interacting with each other either directly or via other nodes.

A sink also known as base station which is situated far away from sensing field. This sink or base station is competent of communicating with the user either directly or through the existing wired networks. The main parts of the network

are the sensor nodes which are required for monitoring physical conditions such as weather conditions like temperature, humidity, intensity, vibration, pressure, motion, pollutants etc. These small sensor nodes, which consist of sensing unit, a processor for data processing, and communicating components, local data storage such as memory unit, Figure 2 shows the structural view of a Wireless sensor network in which sensor nodes are represented as small circles. A sensor node mainly contains four components: sensing unit, local memory storage, central processing unit (CPU), power supply unit, and communication unit. These components are assigned with various tasks and each individual unit is responsible for their own task.

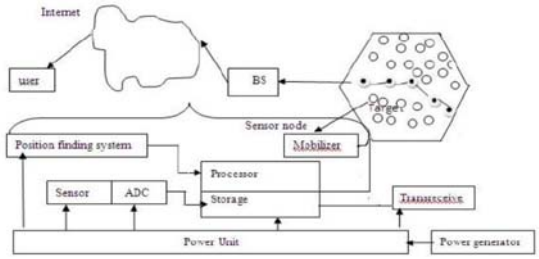

fig 2 .Sensor nodes scattered in a sensor field and components of a sensor Node

The sensor units consist of sensor and ADC (Analog to Digital Converter). The sensing unit is accountable for sensing data as per ADC commands, and then returning the analog data it senses. ADC is a converter that communicate the CPU what the sensor unit has sensed, and also commands the sensor unit what to do. Communication unit is responsible to receive command or query from and transmit the data from CPU to the base station or sink. CPU is accountable for performing data operations such as data removal, data aggregation etc. Power unit supplies power to entire nodes system

Each node may also contain two optional components such as location finding system and mobilizer to understand the knowledge of location with high accuracy.

IV. WIRELESS SENSOR NETWORKS APPLICATIONS

According to literature survey the applications [11] of WSNs can be categorized into defense applications, forest applications, medical science applications, Domestic applications, and industrial applications:

A. Defence applications: WSNs can be an essential part of defense command, security control, data communications, computation, intelligence, targeting systems such as (C4ISRT), surveillance, investigation etc.

B. Forest applications: Some environmental applications[11] of sensor networks include tracking and recording the movements of small animals ,birds and insects, monitoring environmental conditions, earth monitoring and exploration,

C. Medical Science applications: Few of the health applications [11] for sensor networks are diagnosing the patients, tracking location and movement of patients and doctors inside hospital etc.

***D.* Industrial applications:** Some industrial applications [2][11] of WSNs are building virtual keyboards, monitoring product quality, environmental control in office buildings, robot control ,interactive toys etc.

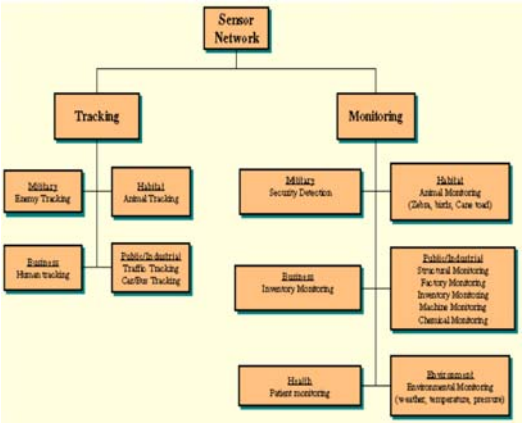

fig.3 Wireless Sensor Networks applications

V.ROUTING SCHEMES IN WIRELESS SENSOR NETWORKS

Routing can be defined as a procedure [9] of finding a path between the source node and the sink or destination node to perform data transmission. In WSNs the network layer is frequently used to implement the routing of the incoming data. As we know that in multi-hop networks the source node cannot reach the sink node directly. That is why intermediate sensor nodes have to send their packets to the destination nodes. The formation of routing tables gives the solution. These consist of lists of node option for any given packet destination.

Routing table is the task of the routing algorithm along with the help of the routing protocol for their construction and maintenance [2] software that requires lots of processing power.

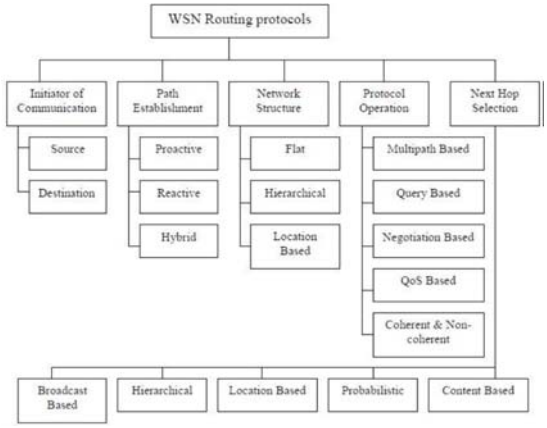

fig.4 *WSN Routing Protocols Classification*

A. Path establishment *Based Routing Protocols*

According to path establishment based routing protocols routing paths are established according to three types; proactive protocol, reactive and hybrid protocol. Proactive protocols are those kinds of protocols that compute all the routes before they are actually required and then store these routes in a routing table present at each node. On the other part, reactive protocols are such kinds of protocols which compute routes only when they are required. Hybrid protocols use a combination of both proactive and reactive routing protocols [6].

1) Proactive Protocols: Proactive routing protocols are such routing protocols which maintain consistent [5] and correct routing tables of all network nodes by using periodic broadcasting of routing information throughout the network. Here in this category of routing protocols all routes are computed before their actual requirement. These routing protocols can be used both in flat and hierarchal structured networks. The advantages of flat proactive routing are their ability to compute optimal path which needed overhead for this computation which is not acceptable in many situations.

2) Reactive Protocols: A reactive routing protocol [5] comes under on demand routing protocol category. So they do not maintain the global information of all the nodes in a network. Here the route establishment between source and destination is based on demand according to the requirement of the network. In order to find out the route from source to destination a route discovery query and route reply strategy is followed. Hence, in reactive routing methodology, route selection is on demand by using route query packets before route establishment.

3) Hybrid Protocols: Hybrid Protocols are combination of both proactive and reactive routing protocols. This routing methodology is applied to large networks. These protocols use clustering approach which makes the network more stable and scalable. The network structure is divided into several clusters and these clusters are maintained dynamically and if a node is added or left a particular cluster then this type of methodology uses proactive technique when routing is required within clusters and reactive technique when routing is required across the clusters.

B. Network Based Routing Protocols

Protocols which are divided based on the structure of network which is very vital for the required operation are comes under the category of network based routing protocols. The protocols comes under this category are further subdivided into three subcategories according to their operations. These protocols are [6]

1) Flat-Based Routing: Flat based routing is required where a large amount of sensor nodes are required and each and every node plays same role. Since here the number of sensor nodes is very large therefore it is not possible to assign a particular identification (Id) number to each and every node. It leads to data-centric routing strategy in which sink node sends query to a group of particular nodes in a sensing field and waits for their responses. Few Examples of Flat-based routing protocols are[5][8][9][10]:

- Energy Aware Routing (EAR).
- Sequential Assignment Routing (SAR).
- Directed Diffusion (DD).
- (MCFA).
- Sensor Protocols for Information via Negotiation (SPIN).
- Minimum Cost Forwarding Algorithm
- Active Query forwarding In sensor network (ACQUIRE).

2) Hierarchical-Based Routings: Hierarchical based routing strategy [10] is best match in those

situations when network scalability and efficient communication is required. It is also known as cluster based routing protocols. Hierarchical-based routing is energy efficient methodology in which higher energy nodes are randomly selected as cluster heads for processing and transmitting data towards base station where as low energy nodes are used for sensing and send information to their cluster heads. In this way hierarchical-based routing helps largely to the network scalability, lifetime enhancement and minimum energy consumption. Some available hierarchical-based routing protocols are; [5][10]

- Hierarchical Power-Active Routing (HPAR).
- Threshold sensitive energy efficient sensor network protocol (TEEN).
- PEGASIS
- Minimum energy communication network (MECN).

3*) Location-Based Routing*: In these kinds of network topography, sensor nodes are randomly scattered in an area of interest and mostly known by their geographic position where they are installed. They are mostly situated by means of GPS technique. The distance between sensor nodes is calculated by the strength of signal received from those nodes and coordinates are calculated by exchanging information between neighboring sensor nodes. Few location-based routing protocols are; [5][8][9][10]

- Sequential assignment routing (SAR).
- Ad-hoc positioning system (APS).
- Geographic adaptive fidelity (GAP).
- Greedy other adaptive face routing (GOAFR).
- Geographic and energy aware routing (GEAR).
- Geographic distance routing (GEDIR).

C. Operation Based Routing Protocols

WSNs applications are categorized as per their functionalities. Hence routing protocols are classified according to their functions to meet these functionalities.

1) *Multipath Routing Protocols*: Multipath routing protocols are those routing protocols those provide multiple path selection for a message to reach its destination thus increasing network performance and decreasing delay in network. Due to increased overheads better network reliability is achieved through sending periodic messages network paths are kept alive and hence greater energy is consumed. Multipath routing protocols are [8][10] :

- Multi path and Multi SPEED (MMSPEED).
- Sensor Protocols for Information via
- Negotiation (SPIN)

2) *Query Based Routing Protocols*: Query based routing protocols works by sending and receiving queries for data. In this category the destination node sends query of interest from a node through network and node with this interest matches the query and send back to the node which initiated the query. The query is normally written in high level languages. Query based routing protocols are [8][10] :

- Sensor Protocols for Information via Negotiation (SPIN).
- Directed Diffusion (DD).
- COUGAR.

3) Negotiation Based Routing Protocols: Negotiation based routing protocols uses high level data descriptors for the removal of redundant data transmissions through negotiation process. Generally these protocols make smart decisions either for communication or other actions based on facts such that how much resources are present. Negotiation based routing protocols are [8][10]:

- Sensor Protocols for Information via Negotiation (SPAN).
- Sequential assignment routing (SAR).
- Directed Diffusion (DD).

4) *QoS Based Routing Protocols*: QoS based routing protocols, network required to have a balance approach for the QoS of applications of system. Here the application can be delay sensitive so to achieve this QoS metric. Here network have to look also for its energy consumption which is another metric when communicating to the sink. So in order to achieve QoS, the cost function for the desired QoS also needs to be mentioned. Examples of such routing are: [8][10]

- Sequential assignment routing (SAR).
- SPEED.
- Multi path and Multi SPEED (MMSPEED).

5) Coherent and non-coherent processing: In the operation of wireless sensor networks data processing is a major component. Hence, routing techniques follow different data

processing techniques. There are two types of data processing based routing [6][7].

6) Non-coherent data processing: In this category of data processing, sensor nodes will locally process the raw data before being transmitted to other nodes for further processing of data. The sensor nodes that perform further processing of data are known as the aggregators.

7) Coherent data processing: In coherent data processing based routing, after minimum processing the data is forwarded to aggregators. The minimum processing basically includes tasks like duplicate suppression, time stamping etc. When all sensor nodes are sources and send their data to the central aggregator node, a huge amount of energy will be consumed and hence this process has a higher cost.

D. Initiator of Communication Based Routing Protocol

Communication Based Routing Protocol relies upon the communication between network components, where generally they remain in sleep mode temporary. In order to get any services required from other network, the sink (destination, base station) node or the source node will initiate the routing with other part to send or receive the control or data packets[6][7].

- Source Initiator Routing Protocol
- Destination Initiator Routing Protocol.

E. Next-Hop Selection Based Routing Protocols

1) Content-based routing protocols: Content-based routing protocols determine the next-hop on the route purely based on the query content. Such type of routing protocols fits the most to the architecture of sensor networks, as the base station do not query specific nodes rather it requests only for data regardless of its origin[5][9][10].

- Directed Diffusion.
- GBR.
- Energy Aware Routing.

2) *Probabilistic routing protocols:* These protocols based on assumption that all sensor nodes are randomly deployed and homogeneous. By using this routing protocol, next-hop neighbour for each message to be forwarded are randomly selected by nodes and probability of selecting a certain neighbour is inversely proportional to its cost [5].

- Energy Aware Routing Protocol.

3) *Location-based routing protocols:* These protocols select the next-hop towards the destination based on the known position of the neighbours and the destination. The position of the destination may indicate the centroid of a region or the exact position of a specific node. The communication overhead caused by flooding can be avoided by Location-based routing protocols, but the calculation of the positions of neighbours may result extra overhead. The local minimum problem is common for all decentralized location-based routing protocols: it might happen that all neighbours of an intermediate node are farther from the destination than the node itself. In order to circumvent this problem, every protocol uses different routing techniques[5][10].

- GEAR (Geographical and Energy Aware Routing).

4) *Hierarchical-based routing protocols*: In case of hierarchical protocols, a message for a node (also called aggregator) will be forwarded by all nodes that are in a higher hierarchy level than the sender. Each node aggregates the incoming data by which they reduce the communication overload and conserve more energy. Therefore, these protocols enlarge the network lifetime and they are also well-scalable. The set of nodes which forward to the same aggregator is called cluster, while the aggregator is also referred as cluster head. Cluster heads are more resourced nodes, where resource is generally means that their residual energy level is higher than the average. The reason is that they are traversed by high track and they perform more computation (aggregation) than other nodes in the cluster. Hierarchical routing is mainly two-layer routing where one layer is used to select cluster heads and the other layer is used for routing. [5][9][10]

- LEACH (Low Energy Adaptive Clustering Hierarchy) protocol.

5) *Broadcast-based routing protocols:* In broadcasting based routing protocols each sensor node in the network decides individually whether to forward a message or not. So the functioning of these protocols is very straightforward. So if a node decides to forward massage, it simply re-

broadcasts the message and if it declines to forward message, the message will be dropped [5][10].

- MCFA (Minimal Cost Forwarding Algorithm).

VI. CONCLUSIONS

Wireless Sensor Networks are one of the promising fields in research area. Wireless sensor networks has a significant feature to observe environmental and physical phenomenon such as temperature, pressure, humidity etc.. In this paper we tried to find out and discussed various aspects of wireless sensor networks and also discussed various types of WSNs and their applications and classify various categories of routing protocols. The routing protocols in WSN has become one of the most significant research areas in WSN is routing protocol and introduced unique challenges compared to traditional data routing in wired networks. The main aim behind the routing protocol design is to keep the sensors operating for a long time, thus extending the network life time. Although many routing protocols have been proposed for sensor networks, many issues still remain to be addressed.

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