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Design Issues of Wireless Sensor Network and Open Research Challenges

Mininath K. Nighot*

Professor and the Head, Department of Computer Engineering, DY Patil College of Engineering, Pune, India.

Abstract

WSN is becoming more popular day by day among researchers due to its vast real-time applications. Various design parameters directly affect the overall performance and lifetime of the network. The design of WSN system is depends upon application. Many parameters need to consider to design WSN system such as number of nodes, types of nodes, routing strategies, way of communication among the nodes and in the network, etc. The network structure and its operations categorize the WSN into flat-based and cluster-based systems. At present, the major challenge is designing and deploying the WSN system. The objective of the paper is to study and analyze all the essential parameters to overcome the challenge. The paper also critically reviews the literature. Finally, the paper is summarized and concluded with open research issues to design robust, low cost, energy-aware WSN systems.

Keywords: WSN, Flat based WSN, Cluster-based WSN, Design Issues, Open issues

Received on 01 August 2020, accepted on 26 September 2020, published on 06 October 2020

doi: 10.4108/_______________

*Corresponding author. Email: imaheshnighot@gmail.com

1. Introduction

Over the last few years, the research community and industry significantly developed an interest in Wireless Sensor Network (WSN) due to its wide range of real-time applications. After the invention of radio communication in WSN, the scope of applications such as rescue & disaster systems, wildlife monitoring, health monitoring, medical diagnosis, agriculture, security applications, etc. have tremendously increased [1] [2]. WSN usually comprises a large number of sensor nodes placed uniformly or randomly in the target area.

A WSN is a communication between sensor nodes and the base station (BS) for data sensing and gathering a wireless communication channel. The sensor node sends sensed data to BS for processing. The processed data by BS is forwarded to the gateway to send it to the internet or satellite [3] [4]. Through the internet or satellite, the data is communicated to the end-users.

The sensor nodes may either be homogeneous or heterogeneous depending on the type of application [5]. Sensor nodes are used to monitor physical and environmental conditions like temperature, humidity, pressure, sound, heat, light, etc. In multimedia WSN applications, sensor nodes are equipped with cameras. As the way of communication in the WSN is merely the exchange of messages among sensor nodes and BS, it leads it to be more applicable in complex and intelligent applications.

1.1 Architecture of WSN

There are mainly two types of WSN architectures [6] [7].

- Flat based architecture WSN architecture
- Cluster-based WSN architecture

Flat based WSN architecture

In the flat based WSN system, BS is generally located at the centre of the network. All the sensor nodes are in the communication range of BS and send sensed data to it. Flat-based WSN architecture is shown in figure 1. It is more suitable for applications where the target is the area is small in size. Whereas for large target areas sensor nodes are not able to communicate with BS directly, then they can be routed through the neighbour nodes to BS [6].

Many design issues have to be taken into consideration such as field environments, network topologies, connectivity of nodes, types of nodes, localization of sensor nodes, data transmissions, energy consumptions, security mechanisms, etc. to design and implement a flat-based system.

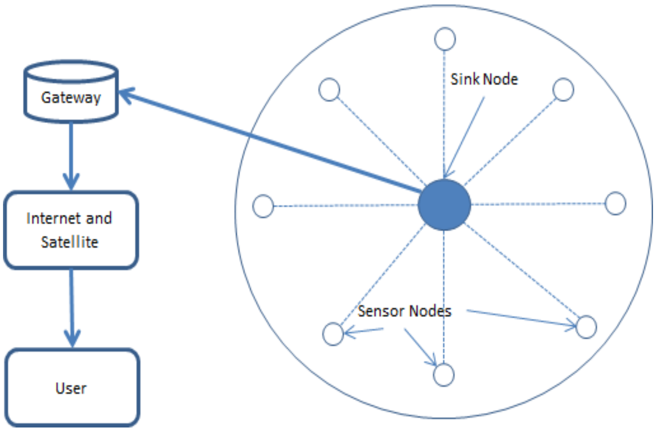

Figure 1. Traditional architecture of WSN [6]

Cluster-based WSN architecture

In the cluster-based WSN system, the target field is divided into several groups, and each group is termed a cluster as shown in figure 2. Each of these clusters works as a flat based WSN system and select CH from among the sensor nodes, instead of BS. Sensor nodes send their sensed data to CH. CH collects the data and aggregates it and transfers it to the BS through other CH if it is not in the communication range of BS [7]. For transmission static or dynamic route is selected. All sensor nodes should be in the communication range of BS is not a must.

To design and implement cluster-based WSN system, many design issues such as cluster formation, cluster head selection, data collection, and dissemination, data aggregation, intra-cluster communication, inter-cluster communication, routing protocols, data load management, relate nodes, latency reduction, node failures, security, and network energy, etc. are detected. A robust system with techniques that are more Innovative and optimized, needs to be designed.

1.2 Global Positioning System (GPS)

The use of location devices is necessary for WSN systems, as they are very useful in detecting sensor nodes, faulty diagnostic mechanisms, and dynamic routing.

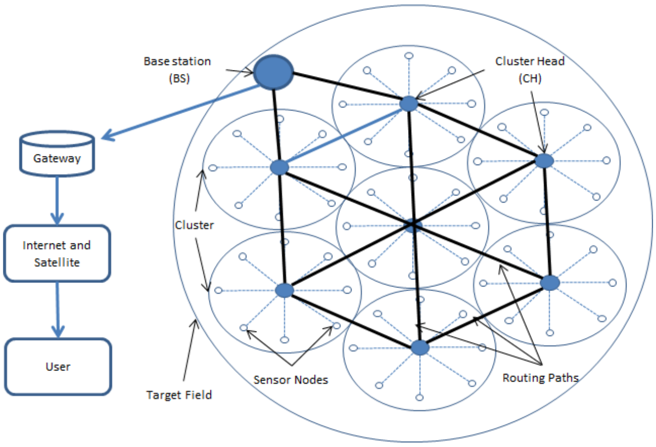

Figure 2. Cluster Architecture of WSN [7]

The GPS systems are found to function efficiently in an open area, but they cannot be used in a closed area. It is a requisite to design a support system for GPS, to give more accuracy and precision and, that is able to operate in a covered area [8]. Some GPS techniques are mentioned below.

Traditional GPS

Satellite-based GPS is a radio navigation system. It provides locations in the 2D space of the GPS receiver if the receiver is placed in the obstacle-free field, and clearly in the line of sight of at least four or more GPS satellites which is shown in figure 3. Its accuracy lies in between 5 meters to 100 meters and precision, 5 meters to more than 20 meters, hence GPS is not advisable to use in WSN because WSN needs more accuracy and precision [8].

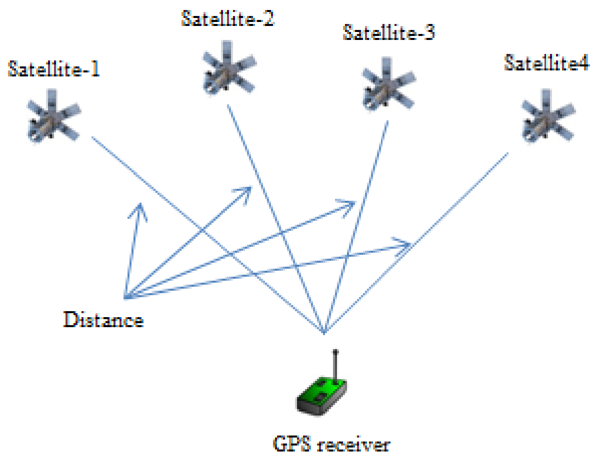

Figure 3. GPS System [8]

Global Positioning System (GPS) with Real-Time Kinematic (RTK)

The authors [9] [10] proposed a more accurate and revised GPS using Real-Time Kinematic (RTK), having multiple rovers, and a GPS base station or receiver, as shown in figure 4.

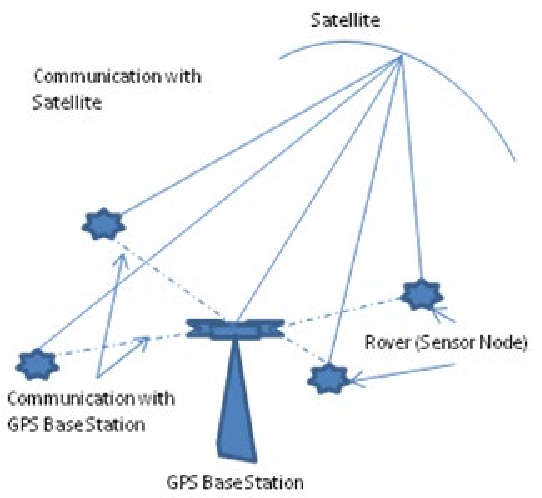

Figure 4. Real-Time Kinematic (RTK) setup [8] [9] [10]

The GPS base station is placed in a location where there are at least, four or more GPS satellites that are in sight. The distance is calculated by a satellite and communicated with the rovers. At the same time, the rover's receiver gets the measurements from the satellites and processes them with the BS information. It calculates their location relative to the base station. The accuracy of GPS based RTK is up to 2 centimetres. This technique can be used in the localization of sensor nodes and routing in WSN [11].

More supportive techniques like these need to be designed with the existing system to give good accuracy and precision.

2 Structure of the paper

The paper is mainly focused on the design issues of Flat based and Cluster-based WSN systems and finally, open research challenges are discussed. All the literature related to WSN is studied in-depth and explained all possible and required parameters in the abstract. The structure of the paper is shown in figure 5.

3 Contribution of the Paper

The prime aim of the paper is to give a brief overview to the beginners or the inexperienced researchers in the field of WSN, regarding the design issues of traditional and cluster-based WSN. It gives brief guidelines to study and implement WSN systems in reality. The author had critically reviewed all essential parameters and extracted all the pros and cons which affect the performance of WSN. The paper highlights the current challenges of the WSN system. Finally, open challenges are mentioned and can be considered as research objectives for further research of the WSN system.

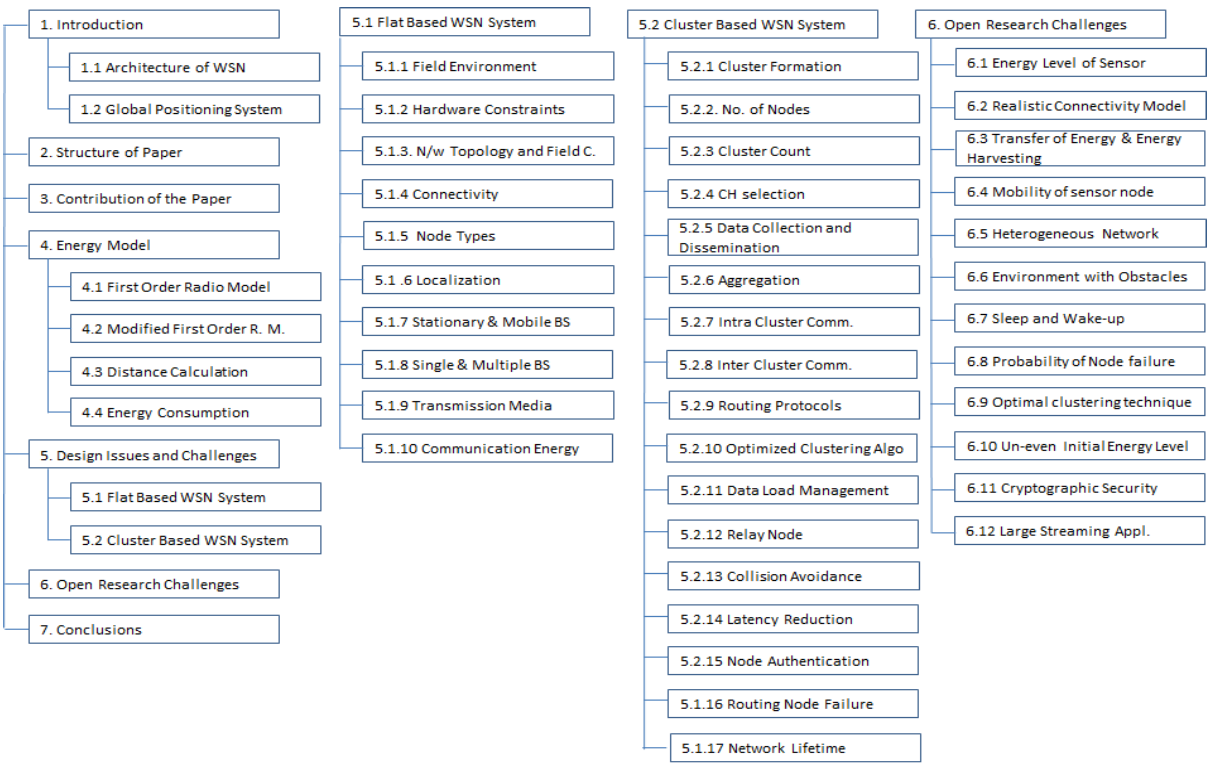

Figure 5. Structure of the paper

4 Energy Model

4.1 First-order Radio Mode

First-order Radio Model is used as stated in LEACH [12]. Radio dissipates 50 nJ/bit to transmit and receive for an amplifier 100 pJ/bit/m^2, the energy loss due to channel transmission 'k' bit message and 'd' distance. The transmitting and receiving energy can be calculated as [8].

Transmitting Energy

$$E_{TX}(k,d) = E_{TX-elec}(k) + E_{TX-amp}(k,d)$$

$$E_{TX}(k,d) = E_{elec} * k + \varepsilon_{amp} * k * d^2 \quad (1)$$

Receiving Energy

$$E_{RX}(k) = E_{RX-elec}(k)$$

$$E_{RX}(k) = E_{elec}(k) \quad (2)$$

4.2 Modified First order Radio Model

To optimize the energy consumption in the network, the clustering approach of nodes is implemented by [13, 14]. Performance in terms of energy consumption is evaluated using first-order Radio Model.

$$E_{TX}(k,d) = \{(E_{elec} * k + \varepsilon_{amp} * k * d^2 \, for k, d \le d_0), (E_{elec} * k + \varepsilon_{amp} * k * d^4 \, for k, d > d_0)\} \quad (3)$$

Receiving energy is the same as LEACH.

The first order radio model is not accurate as it is not considering listening power consumption in the networks. It also assumes that the communication range of the sensor node is unlimited. A novel discrete model must be applied to calculate the energy calculation of the node.

The total energy i and E_i are computed as follows [15]

$$E_i = \sum_{Statej} P_{Statej} \times t_{Statej} + \sum E_{transmissions} \quad (4)$$

Whereas-

- State j- the sensor's energy state (sleeping, receiving and transmitting)
- P_{statej}- Consumption of energy to each statej.
- T_{statej}- time consumed in respective state
- $E_{transmissions}$-the power consumed in transitions between states.
- The values of P_{statej} and $E_{transactions}$ can be taken from [16].

4.3 Distance Calculation

Longitudes and Latitudes can be received from GPS and distance between two nodes can be calculated. It is similar to calculation of two points in 2D plane by Euclidian distance formula [11].

$$LongDist_{AB} = Long_B - Long_A$$ and

$$LatDist_{AB} = Lat_B - Lat_A$$

$$Dist_{AB} = \sqrt{(LongDist_{AB})^2 + (LatDist_{AB})^2} \quad (5)$$

4.4 Energy Consumption

The operations of sensor nodes are broadly classified into sensing, CPU processing, the transmission of data, receiving of data, nodes in idle state, and nodes in the sleep state. The maximum power consumption occurs when the sensor nodes are in the idle state and for transmitting and receiving data. The node which is active and not performing any task, is in the idle state. In this state, transmitters and receivers are active even though they are not performing any task. Sleep state is the state when the node is active but, not performing, sensing, nor processing, and the transmitter and receiver are in off mode. So, in the sleep mode very less energy is consumed [17]. Approximate energy consumption is shown in figure 6.

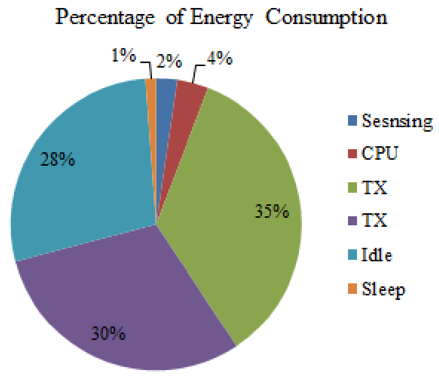

Figure 6. Percentage of energy consumption of sensor nodes [17]

5. Design issues and Challenges

Now a day WSN system is applicable in real time and more complex applications. The technology is also growing simultaneously so there is need of more research in the existing design techniques to satisfy current applications need. It is a challenge to design the WSN as various factors need to be considered depending mainly on the type of application and type of target field. Accordingly, sensors and have to be designed, and other strategies need to be implemented. There are mainly two types of WSN systems flat-based WSN systems and cluster-based WSN systems [6] [7]. The design issues of both are different which are stated below.

5.1 Flat based WSN systems

Flat based WSN systems are generally deployed in smaller areas. The issues and challenges to design it are as follows:

Field Environment

Nowadays, WSN systems can be implemented on plain ground, hilly area, rainy forest, underwater, multi-storage buildings, city squats, etc. While designing WSN systems the consideration of field environment is very much important. The actual field decides the type of sensors, localization strategies, network topologies, routing protocols, information collection policies that are to be implemented [1] [2] [6]. For example-

Underwater WSN systems have some of the major design challenges -

- Selection of sensors which work efficiently in water and water pressure
- Selection of sensors as per communication and sensing range (range of communication reduces due to water medium)
- Sensor coverage
- Real-time communication
- Communication / Routing protocols
- Energy-saving approach etc.

Hardware constraints

The WSN Systems consists of four main components sensor nodes, base stations, communication media, and gateways. These components transmit the sensed information to the world via the network or internet. Sensor nodes are made up of four elements: sensing element, processing element, transceiver element, and battery power element. It also encompasses the location finding element, and mobilizer element [18] [19]. The architecture of the sensor node is shown in figure 7.

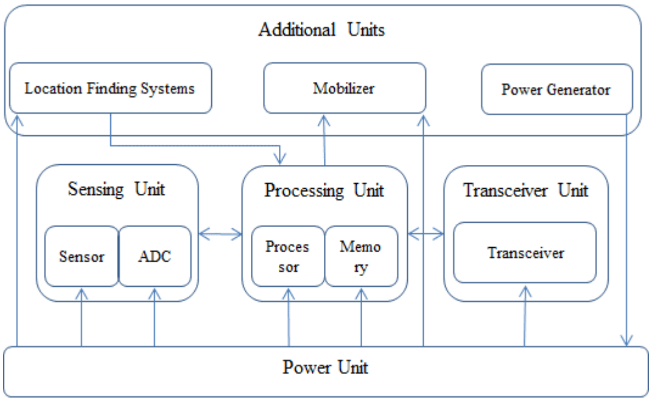

Figure 7. Architecture of Sensor Node [18] [19]

These elements are packed in one unit called a sensor, as per the requirement of application and budget cost of the system, its size, processing power, battery power, and sensing capacity varies. The components of sensor nodes are shown in figure 8. The weight and size of the sensor also vary as per the application, undersea applications require heavy sensors, and air applications lightweight sensors. [18]. A few design challenges of the sensor nodes are mentioned below-

It should -

- Utilize less power
- Be flexible to the environment
- Be replaceable and cheap
- Work in high volumetric densities
- Be operated autonomously.

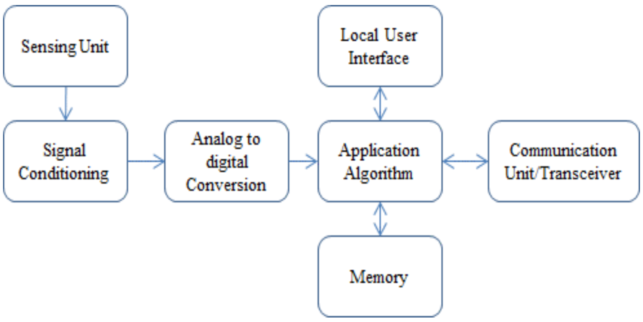

Figure 8. Basic Architectural components of Smart Sensors [18]

The base stations (BS) have to be localized in such a way that they can gather information from sensors and transmit them to the gateway. This affects communication in terms of a range of sensors. Communication media may be air, water, underground, flat ground, uneven ground, smoke etc. The additional units such as GPS modules and

The sensor node has two ranges one for sensing and the other for communication with further sensor nodes and BS. Searching Range (SR) of the sensor node is a range or radius of the node in which it can sense the required parameter from the assigned area. Communication Range (CR) / radio range is a radius of a sensor node in which it can communicate with each other [18]. The sensing range and communication range of the sensor node is shown in figure 14.

After sensing data, the sensor node transmits data with or without processing to CH as per the communication range. Sensed data is stored in the memory if the CH is not in the communication range of the sensor node due to some reason, and transmitted whenever CH will be in range. If the CH is too far than its communication range, then through the static or dynamic path, data will be transferred through other sensor nodes of the same cluster to CH. Generally, CH is always in the communication range of the sensor node of the same cluster [32].

Most of the sensor nodes send sensed data without filtering at their end. CH has to process the received data and aggregate it. But at the end of the sensor node itself, if data is processed and only required data is transmitted to CH then CH may save a lot of time and energy. This technique also reduces the packet size for the transmission of the sensor node to CH and ultimately less energy will be required for the transmission. So it can increase the overall lifetime of the cluster and ultimately of the network.

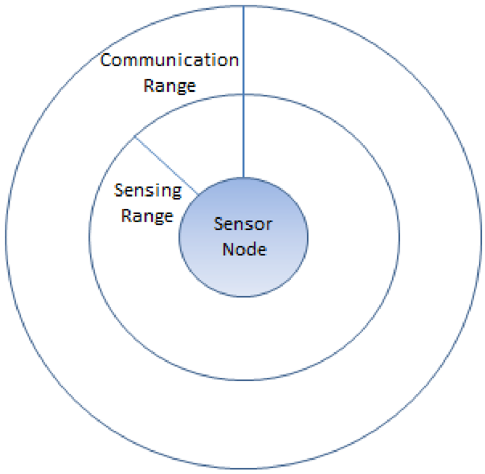

Figure 14. Sensing range and communication range of Sensor node [18]

Aggregation

In a cluster, all the sensor nodes send sensed data to CH. CH has a lot of duplicate data sent by all sensors. To reduce the data duplication and convert it into a required and transferrable format is called aggregation. In some applications where confidentiality is a prime factor, data transmitted in the encrypted form [6].

Still, there is wide scope to find novel techniques of data aggregation and encryption because it is directly proportional to several bits transmitted in the network and it consumes more energy.

Intra Cluster Communication

Generally, single-hop communication is adopted in intra-cluster communication. Sensor nodes send their data to CH if it is in the range of direct communication, otherwise, multi-hop communication strategy needs to use. If multi-hop communication is adopted and filtering of data is not performed by the sensor node, then, more energy is wasted to transmit huge unstructured and duplicate data. The sensor node should have a mechanism to compare, last sent data, and current sensed data. If it is the same, then it should be avoided to transmit [33] [37]. Only one message needs to be transmitted; 'No Change' so that CH realizes that there is no variation in the data and, last received data can be considered for the processing or, avoided. So, it saves energy. Thus, it is not advisable to apply multi-hop communication in the same cluster. Star network topology is preferable for single-hop communication.

Inter-cluster communication

The cluster-based WSN system has multiple clusters and respective CHs. CH transmits data directly to BS like star topology if, BS is in the communication range of it. But, if the BS is far away then, the data should be transmitted through other CH, which is called multi-hop communication. The path may either be static or, dynamic. The static path is predefined. The drawback of the static path for routing is, the CHs which are on routing path drain more energy. Generally, dynamic route-finding techniques are used for multi-hop communication. Dynamic path selection increases the overall lifetime of the network, but it requires extra energy for the process. Even though a lot of novel ideas have been invented to reduce the use of energy, the network, still needs a better generic and optimized technique that consumes less energy [33].

Routing Protocols

Routing protocols decide the way of transmission of data to BS. There mainly two cases as shown in figure 15.

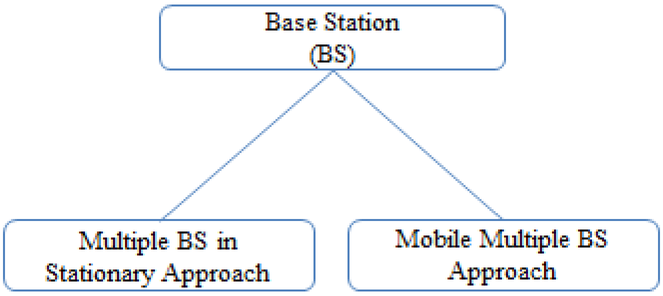

Figure 15. Types of Base station

The network, which has a movable BS, proves more challenging to track the BS. The BS may follow the predefined path to cover all the CH in all the clusters to receive data from CH. The BS needs to broadcast a signal to its neighbour CH nodes once it changes its location, then CH initiates data transmission as BS is in the communication range.

BS changes its location again after receiving the data. For the data collection, multiple BS can be used for a large target area. All or some of the BS can follow the static or dynamic path for moving [1]. Due to the environmental condition and the type of the target area, movable BS cannot be applied to all applications, in such cases, stationary BS is preferred. It also follows static and dynamic route selection to transmit the data. Static path selection is easy to implement but the drawback is the CH nodes which are near to BS, drains more energy, as they need to route more packets as compared to other outer CHs.

In dynamic path selection, at every hop, the decision-making mechanism is required to select the next-hop as per its energy and the distance from BS. The path may not be the same at every routing. Dynamic route selection is widely used in cluster-based WSN. Dynamic route selection requires processing and energy at every hop and consumes more energy, so the invention of an optimized technique is essential.

Optimized clustering algorithms

In stationary BS, dynamic path selection is a challenging task. It is a non-deterministic polynomial (NP-Hard) problem. There is no effective linear solution to it, so, an optimization technique helps to improve the network lifetime and routing efficiency [22].

Several optimization techniques like fuzzy logic, genetic algorithm, neural network, reinforcement learning, and swarm intelligence are used in the literature. Among all swarm intelligence technique is mostly used by a researcher which includes Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO), Bee Colony Optimization (BCO) [38] [39].

Many of the researchers have implemented hybrid optimization techniques for the routing data but still, there is a need to find a generic solution, which will be applied to most of the applications.

Data load management

The transmission of data in the network must be managed and routed optimally. The CH node near to BS, due to heavy load traffic of data, drains off more energy as compared to distant CH nodes. Some researchers suggest that the size of clusters that are near to BS must be small as shown in figure 16. So, CHs of those clusters will require less energy to process aggregation and transmission of data. Some researchers have pointed out that, a separate group of routing nodes should be located near to the BS so that, they will only involve in receiving and transmitting of data to BS as shown in figure 17. By observing the overall network energy utilization of nodes, mostly CH nodes drain off early, so there is a need to find some alternative solutions on load management so that, the overall network energy level will be maintained [24].

Relay node

The concept of a relay node is when any node fails to sense or transmit data in the routing path due to failure or other reason, standby or relay node takes its position.

Collision Avoidance

Collision avoidance strategies need to apply to CH for two reasons. First is the flooding of data by sensor nodes to CH and second is at the same time when another CH sends data to transmit to the next hop or BS. Such instances may invite collisions. To avoid the collisions unique time slots need to be provided for each sensor node, or neighbouring CH. The highest priority can be assigned to data transmission of CH to CH communication, as it effects on latency time [33].

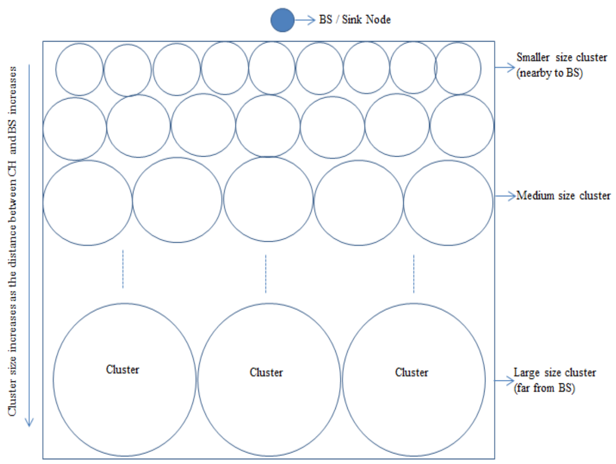

Figure 16. Architecture of unequal clustering in WSN

The relay node may be static or movable. The network should have the mechanism to identify the location of the failed node so that, the relay node can take its place manually or automatically, a movable relay node [40]. The applications in which there are limitations for the installation of the node, it may face the problem of locating relay nodes also.

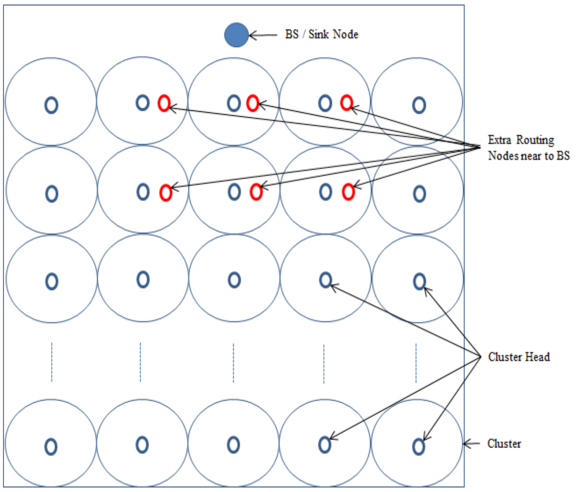

Figure 17. Extra routing nodes near to BS

Latency Reduction

The total time needed to transmit information from source CH to BS is called latency time. Due to the improper load management at CH, channel bandwidth, availability of route nodes, non- optimal path selection, the latency time may increase. Routing paths should be always shortest, optimal, and obstacle-free to reduce latency time [33].

Node Authentication

Any malicious new node can be the part of a network and harm the network or steal the information. So a strong authentication strategy must be applied to a new node entry in the network. Only authentic nodes should take part in the communication and sense of data. Any intruder can disturb the network operation [41] [42].

Routing Node Failure

The causes of node failure are lack of energy, physical damage, malicious attack, not in a coverage area, failure of communication link etc. If any routing path node fails due to the lack of energy or other reasons, the system should find an alternative path for transmission. In static path selection, if any routing node fails, then part of the network will be isolated even though the isolated network works fine. There should be a mechanism to assign the responsibility of routing to its neighbour node or replace the node [43].

Network lifetime

As the sensor node has limited energy and there is no provision to recharge it, it is essential to utilize the available energy efficiently. While designing intra-cluster and inter-cluster communication, dynamic path selection, aggregation, and CH selection, the energy parameter must be considered, and optimization techniques need to be applied. It will help to extend the overall lifetime of the network [44] [45].

6. Open Research Challenges in WSN

As WSN is the most demanding technology due to its huge number of applications, more researchers are focusing to optimize the existing techniques and trying to find novel techniques for the problems. There are many open issues in WSN some of them are stated below.

6.1 Energy Level of Sensor

The variations of radio performance depend upon the energy level of the sensor node. The reasons for radio variations are due to anisotropy, variations in direction and, the heterogeneous energy level of sensors [17] [33].

Anisotropy is at various directions' path loss, observed while transmitting a signal by the sensor node. Path loss is due to incremental changes in the propagation direction of the transmitter. At a certain period, the remaining energies of all nodes are different due to the power consumption of sensor nodes for operations. The energy level of sensor nodes affects communication and data transmission.

6.2 Realistic connectivity model

It is assumed that the communication range is approximately twice more than the sensing range of the sensor node in literature [6]. While designing protocols for routing, it is also assumed that the link quality is the same for the nearest possible distance and maximum possible distance as per the communication range of the sensor node. These assumptions are not always correct. Link symmetry is one of the features of WSN and weakens as the distance increases. It effects of packet loss, packet delay, and overall transmitting and receiving speeds. Communication link quality should not be associated with distance [46].

RSSI (Received Signal Strength Indicator) and LQI (Link Quality Indicator) are the two standard link quality metrics to be considered. Signal strengths can be checked by the RSSI parameter at the receiver end while receiving the packet. The strength and quality of the packet which are received can be checked by LQI.

6.3 Transfer of Energy and Energy Harvesting

Mainly the energy consumption of the sensor node depends upon the processing load, receiving, and transmission of the data. So every node is having a different level of residual energy. It is an open research challenge to transfer node's energy from one node to another [20]. So that the node which is about to die can get energy from the other node which has a good amount of energy. It may broadcast the energy by predicting the energy level of the respective nodes, whether it is below the threshold level or not. If it is possible to transfer then, the overall network lifetime will increase.

If it is possible to charge the nodes wirelessly, from a remote place by broadcasting from fixed or, mobile energy sources then, the energy issue of WSN will permanently be overcome. Energy harvesting is one more research challenge. Each sensor node needs to be equipped with; energy harvesting equipment and gets charged generating power from the natural resources as a requirement arises.

6.4 Mobility of sensor node in WSN

The mobile sensor node can cover more areas than static sensor nodes. The mobility of WSN can be constrained, random, or predefined. Adequate coverage is achieved in constrained movements [11] [22]. The Random movement moves the MSN in any direction, but it is assumed that to transmit the data, the MSN will always be in the communication range. The Predefined moves of the MSN, is a fixed path which is set at the time of deployment of the system. MSN's mobility reduces the number of SSN's in the network, so there is a need to focus on the research in the mobility of the sensor nodes, its communication, and routing strategies. It improves the quality of coverage, connectivity & overall lifetime of the network.

6.5 Heterogeneous Network

In the literature, most of the work is proposed on homogeneous WSN systems where all the nodes are of the same configurations [22]. There are some applications where different sensor nodes deployment is essential. So, there is a need to focus on a heterogeneous system and its operations like communication strategy between sensor nodes, data routing strategy, path selection, security measures, etc.

6.6 Environment with obstacles

In the existing research, most of the researchers have presumed a plane and obstacle-free target field. It is not always possible in reality to have an obstacle-free target field. The researchers have also assumed circular sensing and a communication range [1]. The range may get changed due to environmental factors such as; shadowing effects, interference in the network, signal strength, and energy of a node, leading to the connectivity issues in the network, so existing proposed protocol fails in such situations. More work is expected on the presence of obstacles and variations in sensing and communication ranges to provide robust solutions.

6.7 Optimal sleep and wake-up of sensor nodes

Many researchers have proposed sleep and wake-up node scheduling. The Sensors that are not required for a short period, some are put in the active mode and some in the sleep mode in this scheduling. In the sleep mode, it shuts itself, and either low power timer or, low power trigger sensing device is on [22] [33]. It automatically emanates in the wake-up mode as expected event triggers at a particular time. Centralized and distributed are the two methods to control scheduling. Centralized scheduling is easy to control but challenging for a dynamic environment. Distributed scheduling works well in a dynamic environment but it always leads to imprecise results [48].

Optimal wake-up and sleep schedules are also studied based on, coverage, probability, periodic and random in the literature. Optimal wake-up and sleep scheduling still a research problem in WSN for efficient utilization of resources and extend the lifetime of the network.

6.8 Probability of Node failure

Failure of the node directly affects the area coverage of the target field. In the target field, where manual localization is not possible, we need to spread the sensor nodes with the help of a drone. There is a chance of physical damage to the components and hardware failures [22].

Another reason for the failure of nodes in environmental factors such as; increase in temperature, pressure, humidity, rain, storm, etc. The failure of the nodes influences the coverage area. In the literature, the node failure issue is less discussed. As it is directly affecting coverage of the target field, it should be focused and investigated more.

6.9 Optimal clustering technique

Most of the researchers have proposed even-sized clusters in the WSN. But in reality, it is not always possible. The drawbacks of even-sized clusters are the clusters and CHs which are near to BS, drains more energy, compared to the outer cluster, as they need to transmit their data and the outer cluster's data too. Hence, the size of the clusters near BS can be reduced. The architecture of unequal clustering in WSN is shown in figure 18. It can extend the overall lifetime of the network [47].

6.10 Un-even initial energy level of sensor nodes

Most of the researchers assumed the same initial level battery power for all the sensor nodes. But, it is not probable in realistic applications. At the deployment level, it is not always possible to have the same battery level due to battery potentials and other initial operations performed. Hence, new approaches need to investigate by considering the un-even initial energy level of sensor nodes that will give different realistic results.

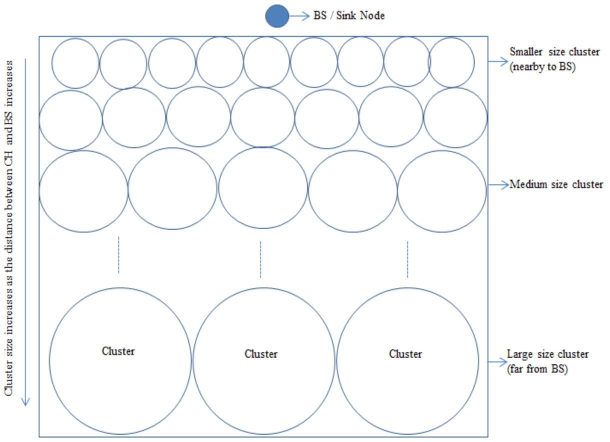

Figure 18. Architecture of unequal clustering in WSN

6.11 Cryptographic Security

Some researchers have proposed cryptographic techniques to encrypt the data for transmission. The traditional ad hoc networks cryptographic techniques cannot be used in WSN due to the limitations of power, processing, and memory. Some lightweight novel techniques need to be implemented which require minimum energy and network bandwidth for the processing and are more secure to transfer.

6.12 Large streaming applications

Nowadays, WSN applications are connected to IoT (Internet of Things) applications which demands huge data transmission in the network. Also, ecological monitoring and multimedia applications need to generate and transmit a huge amount of data. It is a big challenge to the researches to design communication, and routing strategies to support a considerable amount of data transmission.

7. Conclusions and future directions

Designing a robust, low cost and energy-aware WSN system is itself a challenge due to the involvement of different design parameters. All the design parameters are surveyed and critically reviewed of flat-based and cluster-based WSN systems. The pros and cons of existing parameters are discussed wherever necessary, and the future scopes are mentioned briefly. Lastly, the current open research issues are discoursed by considering the future of WSN technology.

In the future, each sensor node should be able to generate power for processing to extend the lifetime. To implement energy harvesting strategies, using natural resources such as; heat, light, and vibrations to WSN.

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