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The Coverage Issues in WSNs

Jyoti Rani[1*] and Vishal Anand[1]

[1]Department of Electronics and Communication, Punjab Technical University, India.

Authors' contributions

This work was carried out in collaboration between both authors. Author JR designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author VA reviewed the paper related to analysis done. Both authors read and approved the final manuscript.

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Abstract

Aim: Wireless Sensor Networks is one of the hot research topic in previous years due to its wide contribution in emerging industry that is Internet of Things. A wireless sensor network is a network of tiny devices, which can gather the information from surrounding and then successfully communicate it via wireless link. WSNs are widely used for monitoring targets in given field of interest. Most popular area of research in Wireless Sensor Networks is coverage. This paper focus on coverage issues in Wireless Sensor Networks.
Study Design: Various Issues in WSNs being studied and analyzed.
Place and Duration of Study: Swami Parmanand College Lalru, between May 2019 to December 2019.
Methodology: It included following steps:-

- Survey of the literature related to the proposed work.
- Comparison of different types of WSNs and challenges and issues related to them.
- Detailed study of coverage issue involved in implementation of WSN.

Results: Coverage selection depends on the system requirement. Each coverage has its own advantages and disadvantages related to its implementation.
"Table 2: Comparison between Various WSN and challenges related to them" it discusses about various types of WSNs and the challenges related to each one of them.

**Corresponding author: E-mail: mandhan08jyoti@gmail.com;*

Conclusion: Coverage in WSNs can be defined on how well the sensor nodes monitor the targets in given field of interest. Each application comes with different set of coverage requirements; hence, deployment strategies are chosen based on the requirements.

Keywords: Wireless Sensor Networks (WSNs); Base Station (BS); Internet of Things (IoTs); Terrestrial Wireless Sensor Networks (TWSNs); Field of Interest (FoI).

1 Introduction

Wireless Sensor Networks (WSNs) consist of many independent, low-cost, low power, lightweight devices that are capable of sensing, processing and wireless communication [1-8]. A Wireless Sensor Network consist of wide number of distributed nodes that work collectively into a multi-hop wireless network. These nodes are sensor nodes, which coordinate among themselves and aim at performing specific tasks.

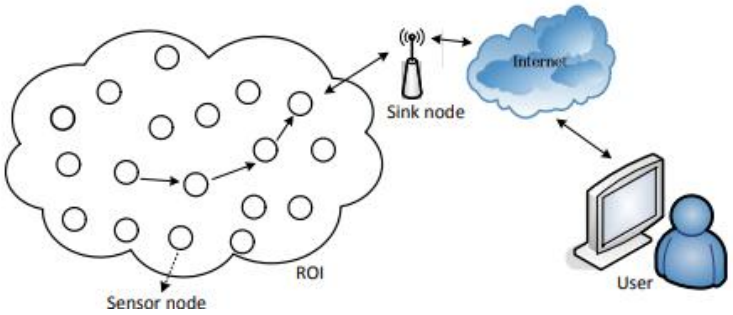

Fig. 1. Wireless sensor network

WSNs are widely used for monitoring purposes and monitoring of targets in given Field of Interest (FoI).

Sensor nods detect the physical stimulus such as heat, light, pressure or sound) and convert them to recordable signal. How well the sensor nodes are monitoring the targets depends on how good coverage the system is providing.

There are various applications of WSNs, which include- industrial, military, health, environmental etc. Different application will require different type of coverage. Therefore, coverage requirements should be kept in mind while selecting deployment strategy for WSNs.

The arrangement of this paper follows: in section 2, we present different types of wireless networks, and its applications. In section 3, we present an introduction to sensor nodes. Section 4, presents various challenges related to wireless sensor networks. Section 5 contains detailed discussion on coverage issue in WSNs. Section 6 contains conclusion, and directions for future researches.

2 Types of WSNs

In this section, we will discuss briefly about types of WSNs, various applications. Below are five types of wireless sensor networks.

Terrestrial WSNs – TWSN consist thousands of sensor nodes deployed in planned or ad-hoc manner.

Underground WSNs-These are costly WSN in terms of deployment and cost of maintenance. Underground WSN consist of underground-buried sensor nodes to monitor the underground conditions.

Underwater WSNs-As the name suggests in this the sensor nodes and vehicles are deployed under water. As compared to terrestrial WSNs, underwater sensor nodes are more expensive.

Multimedia WSNs- Used for monitoring the images and audio-video multimedia files**.** These sensor nodes connect over a wireless connection for data retrieval, processing, correlation, and compression.

Mobile WSNs- These use movable sensors, making them more useful as they can cover wide range of area.

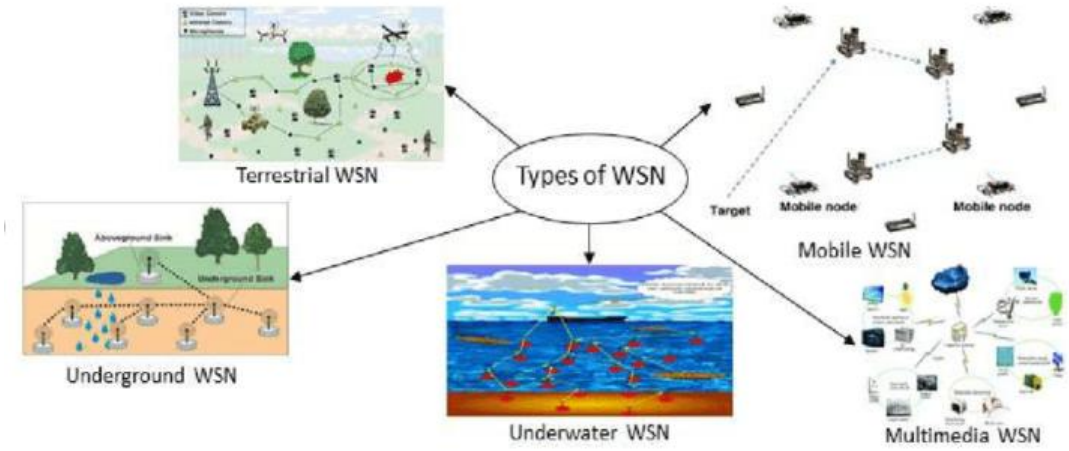

Fig. 2. Types of WSNs

WSNs can be classified as structured or unstructured depending on the sensor deployment.

In an unstructured WSN, the sensor nodes deployed in an ad-hoc manner and the sensors being deployed in dense manner.

Whereas in structured WSN the sensors are less in number and deployed in planned manner and at specific locations making them less expensive and easily manageable.

Table 1. Comparison of unstructured and structured WSNs

	Unstructured WSNs	**Structured WSNs**
Nodes	Dense	Less number
Deployment	Ad-hoc	Pre-planned
Maintenance	Difficult and costly	Easy and cheap

2.1 Applications of WSNs

WSN is widely used for monitoring and tracking applications in various domains. With the rapid technological development of sensors, WSNs have become the key technology for IoTs [9]. Recent advances in wireless communications and electronics have enabled the roll-out of low-cost, low-power and multi-functional sensors that are small in dimensions and communicate well [10]. Nowadays there's too many Benefits of WSN so it is used widely in many applications [11,12].

WSN's are widely used in following applications:

- Military Applications
- Health Applications

- Environmental Applications
- Home Applications
- Commercial Applications
- Area monitoring
- Health care monitoring
- Environmental/Earth sensing's
- Air pollution monitoring
- Forest fire detection
- Landslide detection
- Water quality monitoring
- Industrial monitoring

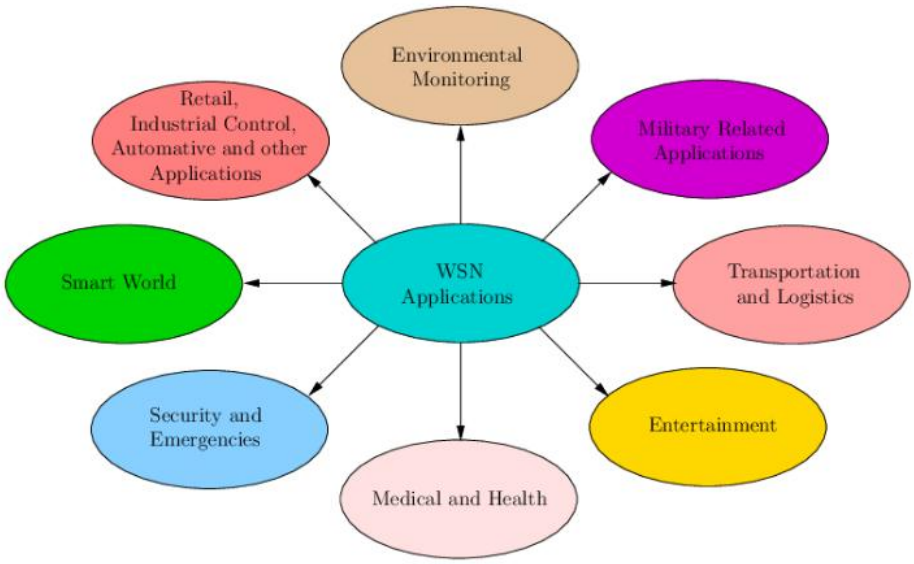

Fig. 3. WSNs applications

3 Sensor Nodes

A wireless sensor network consist of thousands of sensor nodes. Fig. 4 illustrate main components of a sensor node.

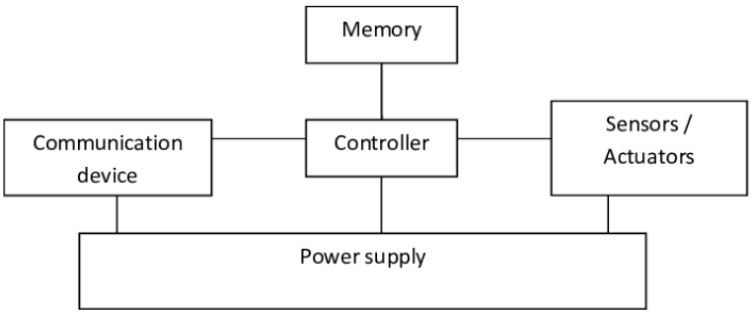

Fig. 4. Components of a sensor node

A sensor node performs multiple functions and it consist of following units: sensor unit, data processing and storage unit, data transmission unit and finally a power supply unit.

These are also known as smart nodes because they do not pass raw data to next node and they use their processing ability to process the data and pass only useful data to next sensor node.

Sensor nodes are self-dependent that is after their deployment they can work without any form of human interference. These nodes sense, collect, process and then transmit data to base station [13-15].

Because of real time data collection ability of WSNs, they have become the key technology for IoTs.

Main components of a sensor node are:

1) Sensing Unit: The sensing unit of a sensor node interacts with the outer world. Sensor nodes in WSNs can be classified into the following two categories: Active and passive sensor nodes. the passive sensor nodes consume less energy than active sensor nodes. Sensor nodes can also be classified into digital and analog, based on signal produced by them. Digital and analog sensor nodes produce binary and continuous signals, respectively.
2) Communication unit: CU of a sensor node is responsible for transmitting and receiving the data packets. The communication between two sensor nodes in WSNs can be classified into one-way or two-way communication [16].
3) Processing unit: PU in a sensor node interacts with the components and executes the software. Different type of processors are used in networks, such as, microprocessors, microcontrollers, low power digital signal processors, communication processors, and application specific integrated circuits based on the task requirements.
4) Storage Unit: Currently sensor nodes have relatively small and low cost storage unit. Such storage unit saves the instruction sets. Mostly consist of random access memory, read-only memory, static random-access memory, and non-volatile memory.

4 Issues and Challenges in a Wireless Sensor Network

WSN's are subject to many challenges related to designing and implementation. These issues contributes in selecting a specific algorithm and protocol for implementing the WSN. Major challenges related to WSN are:

- Design Challenges:

The major issues which need to be studied before designing a WSN are marked below-

1) Life Span- to increase the lifetime of the network each sensor node should use minimum power for their functionality.
2) Cost- the cost of WSN is directly proportional to number of nodes used in system. More nodes means more cost and reduction in sensor nodes reduces the overall cost of WSN but protocol designer should take in consideration that very less number of nodes will not be able to make the WSN work efficiently. Therefore, sensor nodes deployment should increase productivity of network with minimum cost involved.
3) Fault Tolerance- It may happen that some sensor nodes fail due to unavoidable circumstances in the network. This failure should not cause overall network failure. If at any given point of time, many nodes fail in the system then the routing protocol should be self-sufficient and intelligent to make new links to route the data to destination. WSN should function smoothly irrespective of node failures and change in topology. WSN should be robust and reliable in all given conditions.
4) Extensibility- at any given point of time WSN might need to increase the number of nodes in network due to requirement or environment so the WSN should be extensible in order to support freshly added nodes in network.

5) Coverage Area/Connectivity - the main aim of the sensor nodes deployment should be wide coverage area. Each sensor node has some coverage area, so all the sensor nodes of a network should be places in such a manner that 360-degree coverage of overall network is present.

- Environmental Conditions:

Performance of WSN depends majorly on environment. Environmental changes have direct effect on performance of a WSN.

One study showed that fog and rain have adverse impact on transmission range of WSN. Another study by Bannister proved that very high temperature affects communication in WSN. Environmental changes hamper performance of sensor nodes by causing inaccurate data transmission.

- Energy:

Most of the energy in a sensor network utilized for sensing, processing, transmission and reception of data. As we are aware that sensor nodes have small size causing small size limitations on battery size. Due to this, these nodes have confined source of energy. The lifetime of the sensor node for a WSN is in direct proportion to its power supply. Hence, the basic challenge revolves around minimizing energy consumption and increasing the life of the network. While selecting protocol one should keep in mind that sensors would use different amount of energy so the protocol selected should be intelligent enough to switch on and off the sensors by analyzing environment and help in optimizing the energy.

- Security Issues:

Security is the major concern after the energy optimization in WSN. It not only affects the functioning of the network but also very important for WSN availability. Security issues of a WSN focuses on below major points-

1) Data Integrity- this ensures the reliability of network.
2) Data Confidentiality- this deals with protecting data while transferring it.
3) Data Availability- this focuses on making network always available even under worse conditions.
4) Data Authentication- it ensures that data is not changed while transmission.
5) Data Freshness- focuses on data transferred being fresh.

Table 2. Comparison between various WSN and challenges related to them

Type	Deployment	Nodes used	Cost	Challenges
Terrestrial WSN(TWSN)	Pre-planned and Adhoc basis. Sensor nodes are densly deployed	100 or 1000 of inexpensive nodes	Least costly	Limited storage capacity and 3-D sensor deployment is difficult
Underwater WSN	Sensor nodes and vehicle are deployed underwater	Less than TWSN	Expensive than TWSN	Deployment Nodes
Underground WSN	Sensor nodes are deployed under ground in a cave or mine	Fewer than TWSN	More expensive than TWSN in terms of maintenance	Deployment of nodes and information collection is alos a challenge
Multimedia WSN	Deployed in pre-lanned manner	Sensor nodes having camera and micro phone are used	More costly	Energy Consumption is high and high bandwidth are major challenges of the multimedia WSN
Mobile WSN	Sensor nodes are capable of moving	Large number of sensor nodes are used	Very Costly	Localization and deployment of sensor nodes to get maximum coverage area.

5 WSN Coverage Issue

The most important task in WSNs is the monitoring of all targets in given Field of Interest (FoI). Sensor node senses the physical stimulus (such as heat, light, sound, or pressure), converts it into a recordable signal, and digitalizes it to make sensory data. This monitors how well the given FoI is monitored by deployed sensor nodes in the network [17-19].

The sensor nodes in WSNs for monitoring the FoI are powered by the batteries. It is vital to reduce the energy consumption of the sensor nodes during this process of monitoring FoI and connectivity of the WSNs. This is because the batteries may not be accessible for recharge and replacement.

Targets or physical stimulus in WSNs can be placed in planned manner inside the FoI, or may be randomly scattered in the FoI, or on the boundary of the FoI. These targets may change their initial position with time. Based on the requirement, coverage can be classified into three main categories: area coverage, point coverage, and barrier coverage [1,20-22].

1) Area Coverage: It is also known as blanket coverage in this the main aim is to cover each point in the area to be covered. Fig. 5 explains the area coverage, here circles represent the sensing range of the sensor nodes.

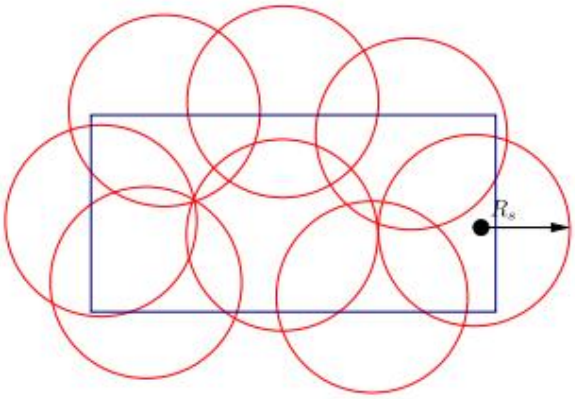

Fig. 5. Area coverage

Types of are coverage depends upon the requirement of coverage needed - full coverage (simple or multiple) and partial coverage. Fig. 6 explains all these types

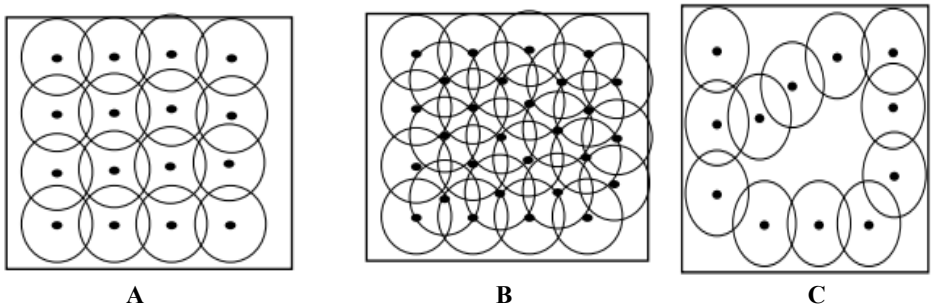

Fig. 6. A) Simple Coverage B) Multiple Coverage C) Partial Coverage

2) Target Coverage: The target coverage, which is also known as point coverage, focuses on monitoring only the given targets in the FoI. The target coverage reduces the energy consumption because main motive is only to focus on given target inside the FoI. The targets are limited in this type of coverage scheme [23].

This type is useful in those applications where only some particular points need to be monitored instead of whole area in FoI. SO there should be minimum one sensor node which will be monitoring the required target. Fig. 7 explains the target coverage – in this red stars indicate target and blue dots are sensor nodes.

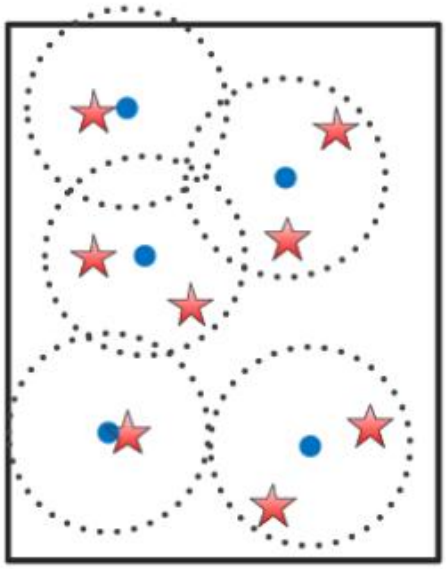

Fig. 7. Target coverage

3) Barrier Coverage: In this, a barrier is constructed to detect any type of intrusion near the barrier. Barrier coverage is also known as sweep coverage. Example of such applications including movement detection are the deployment of sensors along international borders to detect illegal intrusion, around forests to detect the spread of forest fire. The major goal of barrier coverage is to detect intruders and if the intruders try to cross the barrier of sensors then the movement will be reported to the sink/base station immediately. Barrier coverage can be classified as weak k-barrier and strong k-barrier coverage [24-27].
In weak barrier coverage, there are some uncovered regions or holes; it only ensures the tracking of the targets moving along congruent paths. Whereas, the strong barrier coverage ensures that all intruders are monitored or tracked by the sensor nodes.

6 Conclusion

Wireless sensor networks are widely used in all major industries these days. This paper briefly discusses the different challenges faced by Wireless Sensor Networks. This paper highlights the coverage in WSNs.

WSN coverage means how well the sensor nodes are able to monitor the targets in FoI.

Based on the requirement of monitoring of the targets, coverage is of three types: area coverage, point coverage, and barrier coverage. Coverage selection depends on the system requirement. Each coverage has its own advantages and disadvantages related to its implementation. The gap between the existing work and practical applications requirements needs to be addressed in future research.

Competing Interests

Authors have declared that no competing interests exist.

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