Chapter

Wireless Sensor Networks: Applications

Bhargavi Dalal and Sampada Kukarni

Abstract

Wireless sensor networks consist of small nodes with identifying component by sensing, computation, and wireless communications infrastructure capabilities. Many path searching means routing, power management, and data dissemination protocols have been specifically designed for WSNs where energy awareness is an essential design issue. Routing protocols in WSNs might differ depending on the application and network architecture. Wireless Sensor Networks (WSNs) provide several types of applications providing comfortable and smart-economic life. A multidisciplinary research area such as wireless sensor networks, where close collaboration in some users, application domain experts, hardware designers, and software developers is needed to implement efficient systems. The easy molding, fault tolerance, high sensing fidelity, low price, and rapid deployment features of sensor networks create various new and thrilling application areas for remote sensing. In the future, this wide range of application areas will make sensor networks an essential part of our lives. However, understanding of sensor networks needs to satisfy the constraints presented by factors such as fault tolerance, scalability, cost, hardware, dynamic topology, environment, and power consumption.

Keywords: Applications of Wireless Sensor Network

1. Introduction of wireless sensor network

Wireless sensor network (WSN) refers to a collection of sensors for observing, monitoring and recording the physical conditions of the environment [1]. After observing and recording the behavior of sensors, consolidating the collected data at a central location is the main task. WSNs measure environmental conditions like wind, humidity, temperature, pollution levels of sound, air and so on [2].

WSNs consist of spatially distributed and independent sensors to observe and monitor physical and environmental conditions. They are helpful to collectively pass recorded data through the network to a central location. Some of the networks are bi-directional, i.e. both collecting data from distributed sensors and supporting control of sensor activity.

Spatially dispersed and dedicated networks help to collect different parameters with special sensors which are included in the WSN. The development of WSN was motivated by mainly military applications such as battlefield surveillance. Nowadays, such networks are used in many applications like industry, consumer applications. Few of the applications such as industrial process monitoring and control, machine health monitoring, and so on.

2. WSN components

The main component of WSN is node. A sensor network generally consists of tens to hundreds or thousands of relatively small nodes, each equipped with one or more sensing devices [3]. Here each node is linked to one or numerous sensors. Each such node normally has several parts: a radio transceiver with an inner antenna or connection to an exterior antenna, a microcontroller, an electric circuit for interfacing with the sensors and an energy source, usually a battery or an implanted form of energy collecting. A node with a sensor implanted may vary in size. Size of a node can be from that of a brick to the size of a grain of dust. The cost of sensor nodes is also variable. They may range from a few to hundreds of dollars, depending on the complexity of the individual sensor nodes. The potential of different properties such as energy and its consumption, memory, computational speed and communications bandwidth varies the size and cost of sensor nodes. Hence, size and cost limitations on sensor nodes result in corresponding constraints on resources. The use of specific sensor nodes with required quality of various properties depends on the application.

The base stations are another important component of WSN. They are one or more components of the WSN with many more qualities like computation, energy conservation and communication to share recorded data. They play a role of gateway between sensor nodes and the end user. These gateways are usually useful to forward recorded data from the WSN on to a central location. Central locations are nothing but the servers. Other special components in WSN are routers. Routers specially designed to compute, calculate and distribute the routing tables.

As of now, we have seen very few but important components of WSN. Following **Figure 1** explains the various components of WSN.

1. Sensor Node

    a. Sensing Unit

        i. Sensor

        ii. ADC

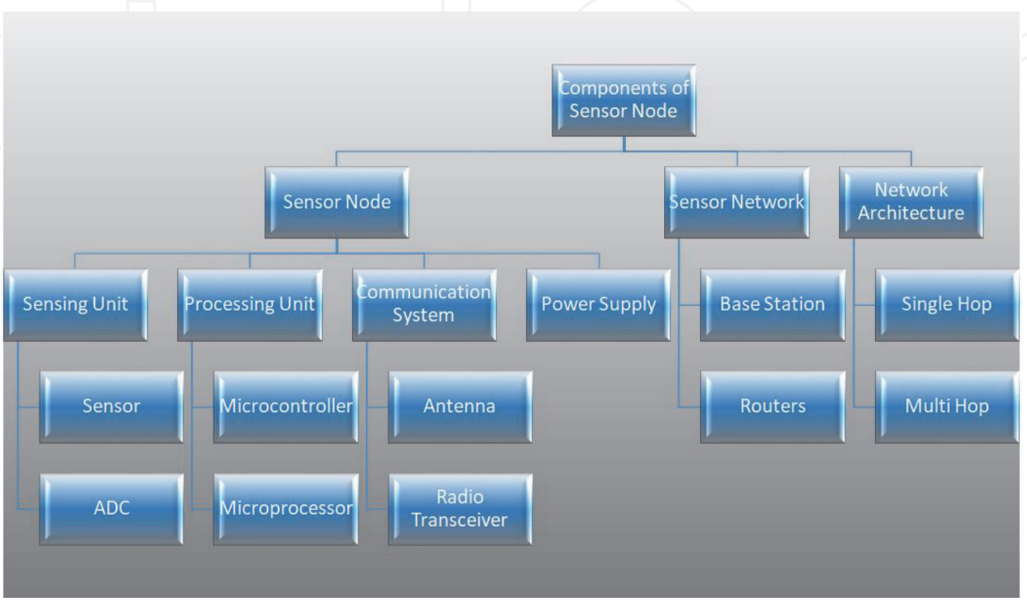

Figure 1.
Various components of sensor node.

b. Processing Unit

i. Microcontroller

ii. Microprocessor

c. Communication System

i. Antenna

ii. Radio Transceiver

d. Power Supply

2. Sensor Network

a. Base Station

b. Routers

3. Network Architecture

a. Single Hop

b. Multi Hop

2.1 Sensor node

A sensor node is a combination of different subunits and all they help to perform the functionality of the sensor node. Different units help to sense, record, monitor and analyze the data which is collected from physical conditions [4].

Even though the name, a Sensor Node comprises not only the sensing component but also other important characteristics like processing of recorded data, communication with servers and storage units to store recorded data. With all these characteristics, components and enrichments, a Sensor Node takes responsibility for data collection, data correlation, and fusion of data from other sensors with its own data and network analysis.

Following figure depicts the same.

The above **Figure 2** shows the sensor node is a combination of different units. They are, sensing unit, processing unit, communication unit and power unit. All of them have their own responsibility to sense data, process data and communicate sensed and processed data to servers respectively. This can be done with the help of a power unit as all the components are low-power devices. And hence a small battery like CR-2032, is used to power the entire system.

The sensing unit comprises sensor and Analog to Digital Converter (ADC). Sensor collects the Analog data from the physical world and an ADC takes the responsibility of conversion of this Analog data to Digital form. The second unit is the processing unit, which is usually a microprocessor and/or a microcontroller. They perform intelligent data processing and manipulation. The next unit is a communication unit consisting of a radio system and an antenna. Here, radio transceivers are used for data transmission and reception and antenna helps to transmit and receive the signals.

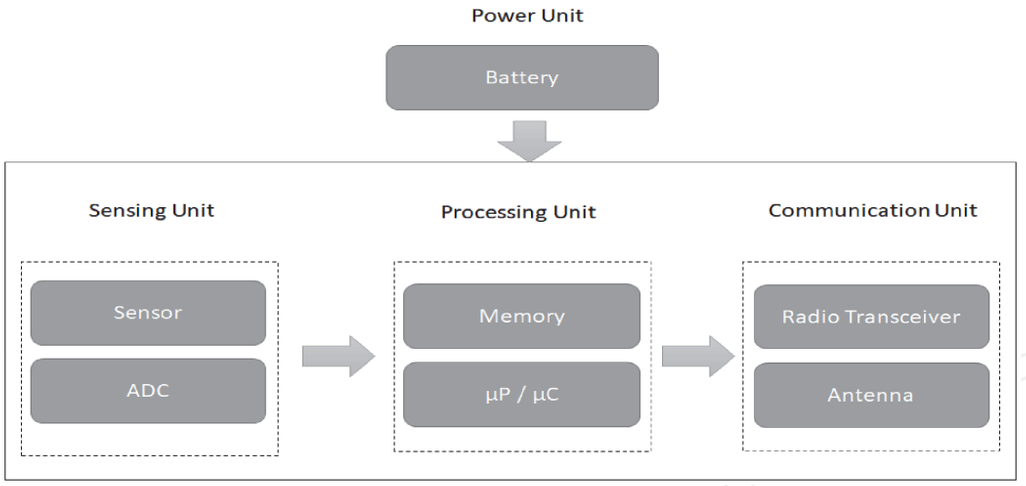

Figure 2.
Sensor node in WSN.

2.2 Sensor network

Till now we have seen that the sensor node collects information from the physical environment and transmits it to the sensor network. Now it's time to learn the sensor network. Sensor network consists of two components. They are namely base station and a router.

Base stations are often thought of as just a central component that is used to gather data from distributed nodes [5]. Here base station acts as a gateway between other networks through the internet. Once the base station receives the data from the sensor nodes, a base station performs some processing on collected data and sends the processed information to the user using the internet.

As we have seen previously, the main task of a sensor node is to sense data and send it to the base station. For the same, a routing path is essential. And this responsibility is handled by a second component of the sensor network. It is a router. For finding the efficient routing path from the source node to the base station there are a lot of proposed routing protocols. The design of routing protocols for WSNs must consider the power and resource limitations of the network nodes, the time-varying quality of the wireless channel, and the possibility for packet loss and delay.

2.3 Network architecture

To observe the behavior of sensors in sensor nodes, and then to communicate with the base station, they must connect through networking. Here is the role of the second component of WSN. It is network architecture. To observe a physical environment co-operatively, a huge number of sensor nodes are arranged in a massive area. That's why the networking of these sensor nodes is equally important. There is communication not only between sensor nodes in a WSN but also with a Base Station (BS) [6]. Here for this communication, WSN uses wireless communication. Hence, this network is named as wireless sensor network (**Figure 3**).

As mentioned above, here in network architecture, there is not only the communication between intermediate sensor nodes or between sensor nodes and base station, the base station also communicates with sensor nodes. The base station sends directions to the sensor nodes. The sensor node performs the task accordingly by working in co-operation with other sensor nodes in the network.

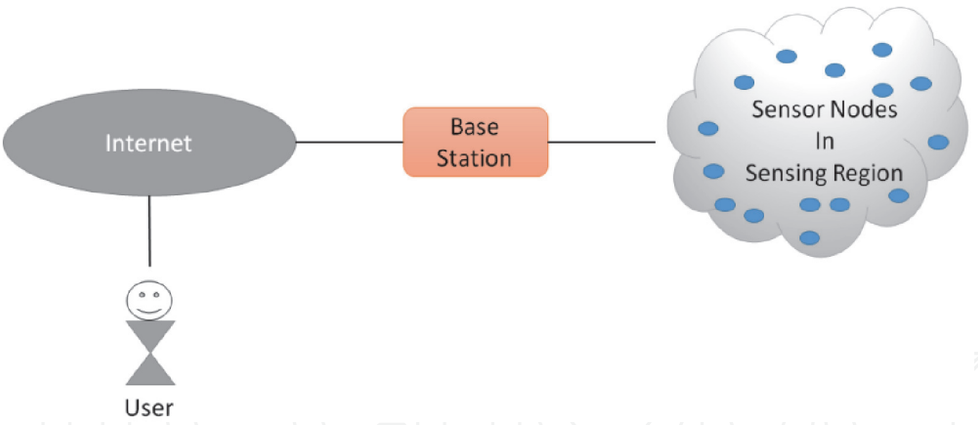

Figure 3.
Network architecture.

Here the network architecture has two main aspects. First one is a single-hop network architecture and the other one is multi-hop network architecture.

Figure 4 explains the concept of single-hop network architecture. In a Single-hop network architecture, each sensor node is connected to the base station. It allows long distance transmission as well. As it allows long distance transmission, obviously the energy consumption for communication will be significantly higher. And hence it affects the tasks of data collection and computation.

As we have seen the power consumption is significantly high in single-hop network architecture, this drawback is overcome in multi-hop network architecture. Hence, Multi-hop network architecture is usually used for better power consumption. **Figure 5** depicts the concept of multi-hop network architecture.

Due to intermediate nodes in multi-hop network architecture, the load of one single link between the sensor node and the base station reduces. Here the data is transmitted through one or more intermediate nodes. Hence, it is more efficient than that of single-hop network architecture.

Multi-hop network architecture can be implemented in twofold. Flat network architecture and Hierarchical network architecture. In flat architecture, the base station broadcast commands to all the sensor nodes but the sensor node with identical query will respond using its peer nodes via a multi-hop path.

In hierarchical architecture, a group of sensor nodes are formed as a cluster and the sensor nodes transmit data to consistent cluster heads. The cluster heads can then communicate the data to the base station.

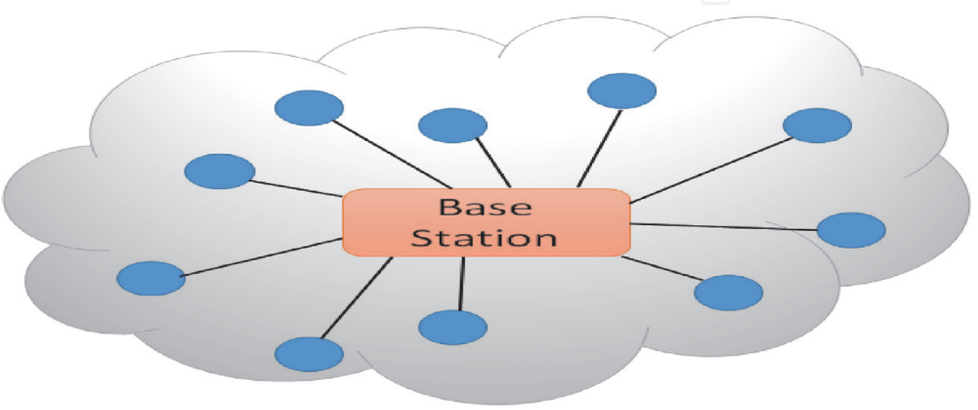

Figure 4.
Single hop network architecture.

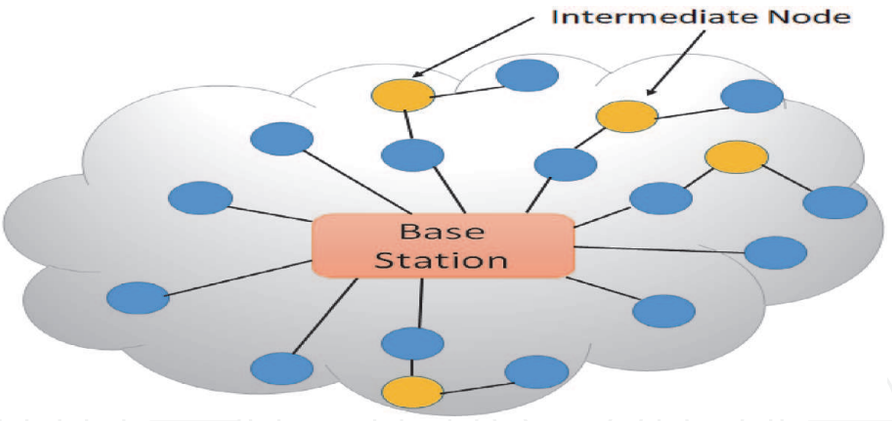

Figure 5.
Multi hop network architecture.

3. Characteristics of WSN

The important characteristics of a WSN include

- Power consumption limitations for sensor nodes.
- Ability to cope with failures of nodes.
- Mobility of nodes.
- Heterogeneity of nodes.
- Homogeneity of nodes.
- Ability to deploy on a large scale.
- Capability to survive harsh environmental conditions.
- Helps to use easily.

These are few major and common characteristics of WSN. But, the characteristics of wireless sensor networks for various applications may be quite different. They also can share common characteristics too.

Sensor nodes have been defined into two characteristics.

1. Static characteristics

2. Dynamic Characteristics

Although here as we mentioned above some characteristics, but now we are focusing on mainly these two characteristics.

3.1 Static characteristics

In fact, such as smart buildings, physical infrastructure or technical experimentations are some applications, where the network is stable i.e. static over the space, having several fixed components in the network is regular solution. The fixed parts

would be connected to the continuous power supply, so that wireless parts can use low power to transfer data to them and also nodes can go in the standby mode from time to time (**Figure 6**).

The characteristics of some applications include low cost, small size, low power consumption, robustness, flexibility, resiliency on errors and faults, autonomous mode of operation, and often privacy and security.

3.2 Dynamic characteristics

An active care approach that is dynamic works as an 'on-the-fly'-based initiating technique that creates a fresh topology when the existing one is no longer ideal. The main advantage of its capability is to create an active prior version, that the system becomes more energy-efficient. These networks are characterized by a need for low power consumption and low levels of physical security and broadcast physical medium. Asymmetric techniques like RSA are not to be used as are inefficient and consume too much power.

3.2.1 Ad-hoc network like MANET

MANET means Mobile ad-hoc Network. It is also named as wireless ad hoc network or temporary wireless network. It usually has a searching path interacting environment on top of a Link Layer ad-hoc network. They consist of set of mobile nodes connected wirelessly in a self-configured, self-healing network without having a fixed infrastructure [7]. These wireless sensor nodes are allowed to move freely on a random basis as the network topology changes frequently. Each node acts as a router as they accelerate traffic to other specified nodes in the network.

Figure 7 shows the structure of an ad-hoc network which consists of a peer-to-peer, self-forming, self-healing network. Typically communicate at radio frequencies (30 MHz-5GHz).

Reconfiguration can be made in such a way that the new network has the same topology (only some nodes have exchanged their places) or allowing any arbitrary topology, also, it is not necessary to modify the routing algorithm.

Figure 8 shows clustered-based wireless sensor networks have been extensively used in the literature in order to achieve considerable energy consumption

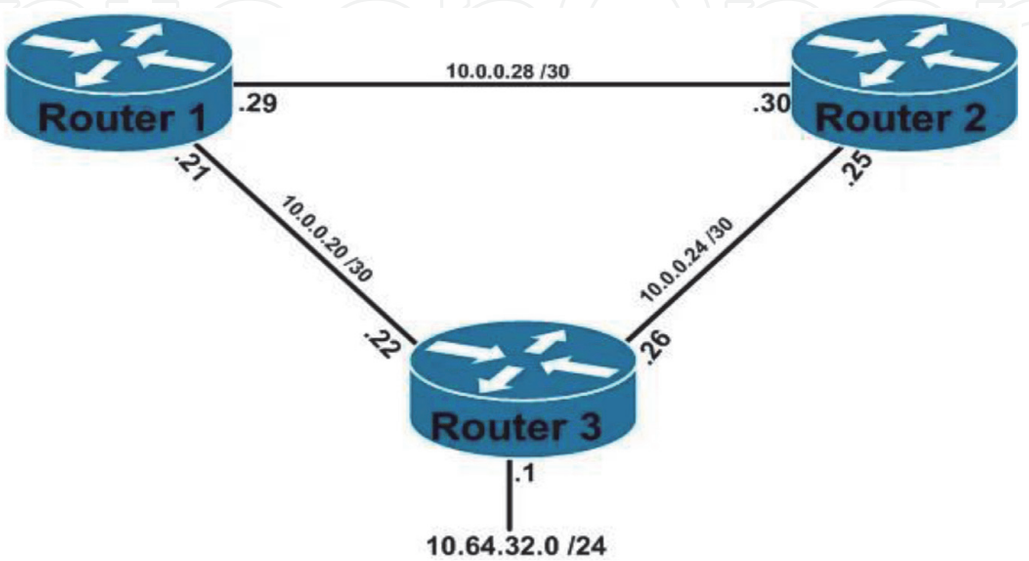

Figure 6.
Structure of static network.

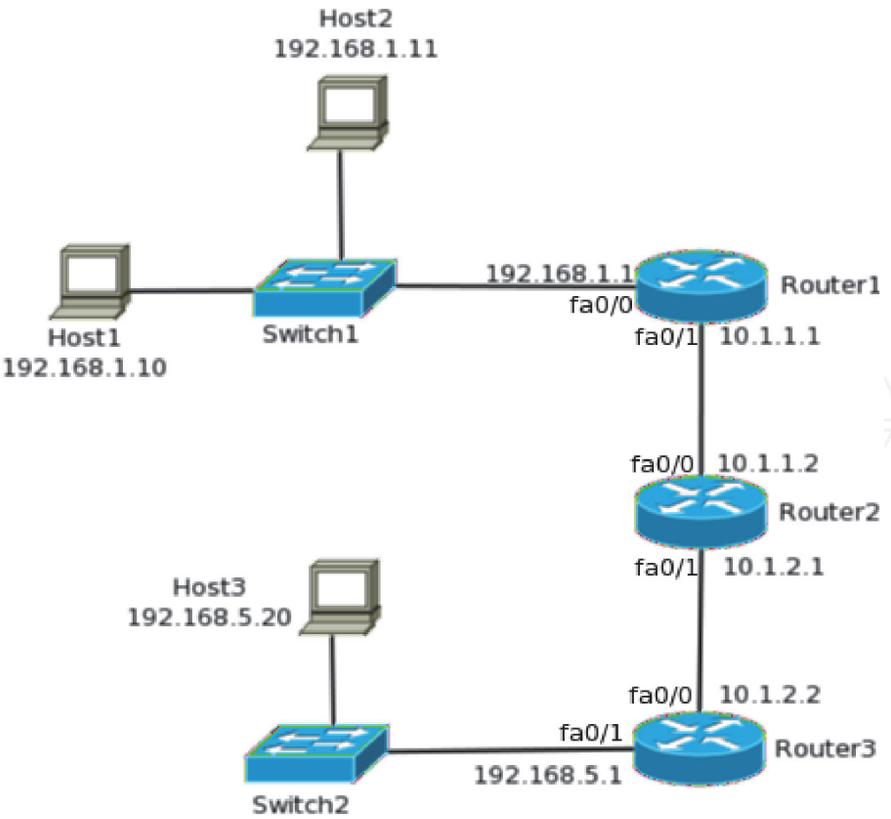

Figure 7.
Structure of ad-hoc networks.

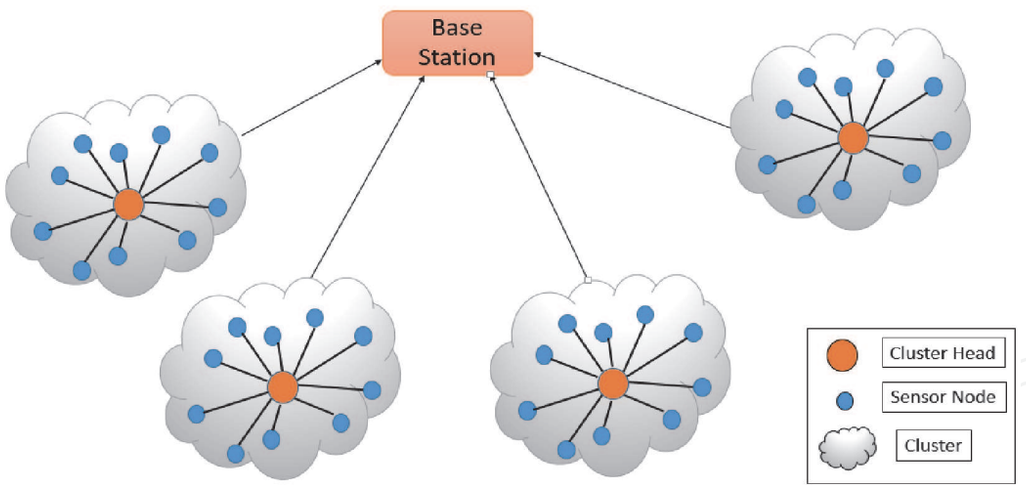

Figure 8.
Clustered-based wireless sensor network.

reductions. The cluster formation phase, where all the dynamic nodes transfer a control packet focused to the sink node in order to be a portion of the cluster. Precisely, the lively active nodes in the managed that controlled area where control packet transmit with possibility 'τ' in each time slot. If there is only a single communication that is only one node transfer, the control packet is well received by the sink node, and the node that successfully transmitted this packet is considered to be already an adherent of a cluster.

As such, this node no longer transmits in the cluster formation phase. The remaining nodes continue this process until all the active nodes successfully transmit their control packet. If there are two or more transmissions in the same time

slot, all transmissions are considered to be corrupted, and the control packets involved in this collision have to be retransmitted in future time slots. Hence, when a collision occurs, none of the involved nodes are aggregated to a cluster.

3.2.2 Some common characteristics

Many of the characteristics may depend on the applications. In some of the applications, it might be acceptable or in some of the applications it might not be that much considered. So, few are the characteristics are common.

Following are the common characteristics that need to be considered while using WSN for developing different applications.

1. Power Efficiency
2. Low power
3. Responsiveness, energy constraint
4. Reliability
5. Data compression
6. Scalability
7. Mobility

Let us see all above mentioned characteristics one by one in detail.

4. Power efficiency

The consumption of Power limits for nodes with batteries. Many of the challenges of sensor networks revolve around the limited power resources. The size of the nodes limits the size of the battery. The software and hardware design needs to carefully consider the issues of efficient energy use. Specific power-management strategies are necessary for WSN nodes that are powered by non-rechargeable batteries.

It is mandatory to note the power eating features of the node in three components. They are the sensing circuitry, the digital processing unit, and the radio transceiver unit.

The sensing circuitry, which consists of the environmental green sensors and the ADC, needs energy for bias currents, as well as amplification and analog filtering.

A node's digital processing circuits are typically used for digital signal processing of gathered data and implementation of the protocol stack.

Two-way communication through radio transceiver unit with other nodes and a remote base station is achieved through a network processor, which packetizes and encodes the data for robustness and security.

5. Low power

The key to accomplish a longer lifespan for WSN is to design with minimal power consumption of wireless sensor nodes, hence titled "low power". To reduce

the overall power consumption, low power WSN controls the lively active time or "awake time" of the devices (such as a radio or microcontroller) and limits the present draw when they are "sleeping." These networks accomplish this by changing the power setting modes of the devices, such as "always on", "standby", or "hibernation" modes. Depending upon the requirement, the nodes and its components may be used in different power setting modes. As the energy policy depends on the application; in some applications, it might be acceptable to turn off a subset of nodes in order to conserve energy while other applications require all nodes operating simultaneously. It helps to work WSN in low power mode.

6. Responsiveness

The sensor nodes need to become independent to work even in bad situations and portrait responsiveness. WSN works more efficiently if sensor nodes develop characteristics of responsiveness without explicit user and/or administrator action. If the network is more responsive, it yields more throughput and obviously increases the efficiency of the network.

7. Reliability

WSNs involve a number of sensor nodes with limited processing, storage, and battery capabilities. The overall reliability of a WSN is enhanced by the reliability of the components of the node. If either of the components fails, the whole node fails. Each component/unit has associated reliability and defined in the software/hardware specification. There are numerous approaches to cut down the power consumption of WSN nodes (increases the network lifetime) and increase the reliability of the network (by improving the WSN quality of facility). As the reliability increases, obviously the capability of the network increases.

8. Data compression

While designing the WSN, it is necessary to reduce the amount of energy used for radio transmission, but nodes can use additional energy for computation and/or filtering. This can be fruitful if data is compressed.

9. Scalability

Scalability of routing protocols used in WSNs is an acute topic due to the tremendously high number of nodes and comparatively high node compactness. A good routing protocol has to be scalable and easily adaptive to the changes in the network topology. Performance of protocol must well as the network grows larger or as the workload increases.

10. Mobility

Mobility in wireless sensor networks is an element which directly influences the network performance. Indeed, with an architecture based on the IP stack, a mobile

Sr. No.	Characteristics	Importance of Characteristics
1	Power Efficiency	This characteristic insists to minimize the power eating property of the node. More power efficient network yields more effectiveness.
2	Low power	The key to achieving a longer lifetime for WSN is to design WSN that minimizes power consumption of wireless sensor devices.
3	Responsiveness	Sensor networks need to become autonomous and exhibit responsiveness without explicit user or administrator action.
4	Reliability	Reliability of the network increases the throughput of the WSN.
5	Data Compression	Nodes can use additional energy for computation and/or filtering. Data compression helps to reduce the stress of the node in WSN.
6	Scalability	A good and adaptive (adapts the changes in the network topology) routing protocol makes the WSN more scalable.
7	Mobility	This characteristic helps to maintain connectivity of mobile nodes with other sensors, also allowing connectivity to the Internet.

Table 1.
A briefed view of characteristics.

node has to maintain connectivity with other sensors, also allowing connectivity to the Internet.

All above mentioned characteristics have their own importance. **Table 1** is a briefing about all the characteristics one by one.

Let us see all above mentioned characteristics in detail along with some applications. Here, applications are included to explain how different characteristics are helpful while developing diverse applications. Keep in mind that these characteristics have their own importance while developing the applications. It's not at all necessary that every characteristic plays a vital role in every application. But, commonly all they help to increase the productivity, efficiency and throughput while developing the application.

Mainly, we are considering three applications while studying the above mentioned characteristics. They are viz. a. Health Monitoring System, b. Military Application and c. Security and surveillance.

a. **Health Monitoring System:**

Here, we will see how above mentioned characteristics are important while developing the Health Monitoring System using WSN. The Bio-compatible wearable sensors allow vast amounts of data to be collected and mined for clinical trials, reducing the cost and inconvenience of regular visits to the physician. There are many aspects in which the health monitoring system works. Like, some advanced techniques are used to track diabetes using a WSN or A blood pressure sensor suitable for wireless biomedical applications. Patients can be tracked and monitored in normal or in emergency conditions at their homes, hospital rooms and also in Intensive Care Units (ICUs) [8]. To develop any of the applications in the Health Monitoring System, let us see how the above mentioned characteristics play a role.

b. **Military Application:**

When WSN is used while developing military applications, again there is a need to think about the importance of above said characteristics. Video sensing is useful in various applications such as: military, environmental, healthcare, industries and surveillance of all its types [9]. To make an

application efficient, it's not at all necessary to incorporate all characteristics. But, those who help to improve the throughput should get consideration while developing the application. As said above, this military application also has many aspects. WSNs can be used by the military for a number of purposes such as Monitoring or Tracking the Enemies, for Force Protection or for Vehicle Navigation systems for the military and so on.

c. **Security and surveillance:**

Each sensor node should have sufficient security mechanisms in order to prevent unauthorized access, attacks, and unintentional damage of the information inside of the sensor node [10]. For this type of application, the nodes are placed at fixed locations to continuously supervise some parameters in order to detect possible anomalies like a fire, a toxic gas, or even a roof failure using micro seismic and rock deformation sensors. Here again, while developing the required application, if important characteristics are taken in consideration, then the developed application will give more efficient results.

Ultimately we have seen that the consideration of characteristics while developing any of the applications helps to give high, accurate and efficient results. **Table 2** helps you to understand the importance of characteristics in all respective applications.

Sr. No.	Characteristics	Importance of Characteristics	Health Monitoring System	Military Application	Security and surveillance
1	Power Efficiency	This characteristic insists to minimize the power eating property of the node. More power efficient network yields more effectiveness.	With more battery life, any Health Monitoring Application works for a longer time. Longer life sensors can monitor the sugar level in case of Diabetes Monitoring system and blood pressure level in case of BP Monitoring system very effectively. If the foreign body needs to embed in the human body, then this characteristic is most important.	As the nodes are dispersed in the field, it's not easy to change or charge the batteries. Power efficient nodes used in many applications in Military is useful for monitoring and protecting military forces from intruders.	In these types of applications, nodes are placed at the same location. They can be charged or changed as and when required. Hence, if this characteristic is avoided upto some extent, then there will not be any harm in the system.
2	Low power	The key to achieving a longer lifetime for WSN is to design WSN that minimizes power consumption of	To increase the battery life, power modes are very helpful. From different components of sensor nodes, we	In many of the military applications, they are developed to monitor the movement of intruders. To	In this application, again, all nodes have to work without sleeping.

Sr. No.	Characteristics	Importance of Characteristics	Health Monitoring System	Military Application	Security and surveillance
		wireless sensor devices.	cannot put the sensor in sleep mode as the sensor has to collect reading continuously in either Diabetes Monitoring System or BP Monitoring System. But the transceiver unit can be on sleep mode when there is no transmission or receiving of data.	achieve this goal, all required nodes and their components have to work continuously. This characteristic cannot be fulfilled in case of many military applications as we cannot put nodes in sleep or in hibernate mode.	
3	Responsiveness	Sensor networks need to become autonomous and exhibit responsiveness without explicit user or administrator action.	To develop a Health Monitoring System, sensor nodes must be responsive to collect data regularly without fail. Nodes have to work autonomously.	In Military Application, sensor nodes must be responsive to collect data frequently without fail. To be responsive, to monitor the actions of the enemy, the network has to work independently in case of any failure.	Here also sensor nodes must be responsive to collect data repeatedly without fail. If the network is not responding continuously, then it will become difficult to give required security in current application.
4	Reliability	Reliability of the network increases the throughput of the WSN.	In account of correctness of reading in case of either application of the Health Monitoring System, reliability characteristics must be reflected while implementing. To detect the sugar level or to monitor BP, the nodes must be reliable. Nodes must read all the readings correctly and reliably. Every component and unit must be capable of handling the unfortunate situations.	To increase the efficacy, all military applications must be implemented with consideration of reliability of sensor networks. Reliability can be increased here by developing nodes who support low power consumption.	With the characteristic reliability, the application of security and surveillance provides more security which is the objective for development of this application. Reliable network supports the security application in case of failure of any of the components or nodes, the whole network must give the required throughput.

Sr. No.	Characteristics	Importance of Characteristics	Health Monitoring System	Military Application	Security and surveillance
5	Data Compression	Nodes can use additional energy for computation and/or filtering. Data compression helps to reduce the stress of the node in WSN.	Data compression and transmission increasingly important in the field of computer communication. Computer-based modeling applications should important to-evaluate medical data communications.	Information processing, fusion, and knowledge generation can significantly enhance the capabilities of military applications of WSNs. It needs to have reliable correlation between all nodes and after data compression challenge is to get processes information efficiently towards destination.	Sequence of characters, image based data, encode multiple correlated data streams when data get compressed for easy reception at destination and need security.
6	Scalability	A good and adaptive (adapts the changes in the network topology) routing protocol makes the WSN more scalable.	Network must respond efficiently in case of changes to the network. If it is a Health Monitoring system, the network must be scalable and adaptable while collecting accurate information.	Routing protocols must perform well as the network grows larger or as the workload increases. Mainly in Military application, the network must be scalable and dynamic in case of any changes so that it can serve effectively.	If the load increases, the network must be scalable. Otherwise, security application cannot give required results.
7	Mobility	This characteristic helps to maintain connectivity of mobile nodes. The performance of the protocol is analyzed for mobility in large networks as well.	In all applications, mobility also plays an important role. In the case of a speed. How health monitoring system can be worked is a big challenge.	In the case of a Military Application, the energy of nodes when moving in sensor environment. And work efficiency also challenging point.	Challenging point is that when nodes coming in working environment where they have to communicate with each other. If any malicious node come through freely moving environment that communication should be very dangerous for all other nodes.

Table 2.
Importance of characteristics with applications.

11. Challenges in wireless sensor nodes in various ways for an application

Challenges in WSN are listed in **Table 3**.

Sr. No.	Parameter	Description	Challenges
1	Energy	Energy is an important factor for sensor lifetime. Energy is consumed for node operations sensing, data collection and network operations like data communications via different communication protocols.	To manage limited battery by designing and implementing various energy efficient hardware and software protocols for WSN.
2	Self-Management	Wireless sensor networks once deployed should be able to work without any human intervention. It should be able to manage the network configuration, adaptation, maintenance, and repair by itself	To manage various unpredictable changes which occurred in the environment like in remote areas and harsh environments, without infrastructure support or the possibility for maintenance and repair they need self-configuration.
3	Hardware and Software Issues:	Energy is an important factor for sensor lifetime. Energy is consumed for node operations sensing, data collection and network operations like data communications via different communication protocols. Platforms which can adapt to run-time situations will play an important role in wireless sensor networks. Hardware/Software configuration move forward complex operations and provides a flexible or easy way for communication mechanisms to deal with complex network structures. Due to small size the nodes have also restricted resources such as CPU performance, memory, communication bandwidth and range. The range of sensor nodes can cover a limited area of the physical environment.	The traditional sensor node architecture, which has software implementation running on a fixed hardware design, is no longer fit to the changing requirements for new upcoming technology. The operation behavior changes because of the application requirements and the environmental conditions To collaborate with other already deployed sensor networks and to maintain an efficient network structure, the sensor nodes require flexible communication capabilities.
4	Operating System	Operating Systems for WSNs should be less difficult than the general operating systems. Application developers create interfaces between the user and the computer hardware and controls the execution of all kinds of programs.	It should have a stress-free programming paradigm. They should be able to concentrate on their application logic instead of being concerned with the low level hardware issues like scheduling, preempting and networking.
5	Quality of Service (QoS)	Quality of service is the needed service which is provided by the sensor networks to its users. Though, it is hard to say, due to the dynamic nature of network topology, and the available state information for routing is inherently rough.	Sensor networks need to be complete with the required volume of bandwidth so that it is able to achieve a minimal required QoS. QoS is a tool that should be designed for an unstable QoS constrained traffic. Many times scalability is the important part of a sensor network. Adding or removing of the nodes should not affect the QoS of the WSN.

Sr. No.	Parameter	Description	Challenges
6	Security	In sensor networks, when there is a consideration of security it is vital for each sensor node and the base station to have the capacity to verify that the data received was really sent by an authentic sender and not by an opponent that tricked legitimate nodes into accepting incorrect data.	Confidentiality is required in sensor networks to protect information traveling from one sensor node to another sensor node of the network. Privacy required in between sensors and base station.
7	MAC Layer Issues	Direct impact on energy consumption, primary causes of energy waste are found at the MAC layer such as collisions, control packet overhead and idle listening.	Power redeem forward error control difficult technique to implement due to its heavy computing power requirements and the fact that long packets are normally not practical.
8	Architecture	Architecture can be considered as some protocol for implementing some functionality along with a set of interfaces, functional internal components, protocols and physical hardware devices.	Limited features in sensor network architecture make difficulties in this field in terms of progress. Durability and scalability is a prime factor in architecture.
9	Data Collection and Transmission	Data collection and decisions is the main objective of sensor nodes. The sensors frequently sense the data from the surrounding environment, process it and transmit it to the base station infrastructure or sink.	Sometimes the specimen of data collected is redundant and it's not necessary to transmit such samples to the sink node as it will only consume energy. So care is important during data collection and transmission.
10	Calibration	Calibration is like a one standard process of adjusting the raw sensor readings collected from the sensors into corrected values by comparing it with some standard values.	Manual calibration or basic reading which is taken for sensors is time consuming and a difficult task. Due to failure of sensor nodes and random noise which makes manual calibration of sensors too expensive.
11	Deployment	Deployment in which implementation of the wireless sensor network takes place in real world location. At some places which are hard to reach, sensors are dumped from helicopters or may be in some locations sensors are placed according to some network topology.	Energy management issues like discharged battery recharge and replacement are cumbersome challenges in real world scenarios. Due to many concurrent transmission attempts made by several sensor node networks, network congestion yields low data.
12	Limited Memory and Storage Space	A sensor is a small device with only a small amount of memory and storage space for the code.	For an effective security mechanism, it is needed to limit the code size of the security algorithm. Building software for the sensor must also be quite small due to limited code size and memory.

Table 3.
Challenges in WSN.

12. The major applications of WSNs

12.1 Application of WSNs

1. **Logistics**

Logistics is a multi-player business which has changed significantly in the last decade. e.g. transport of food. **Figure 9** shows one application scenario, where

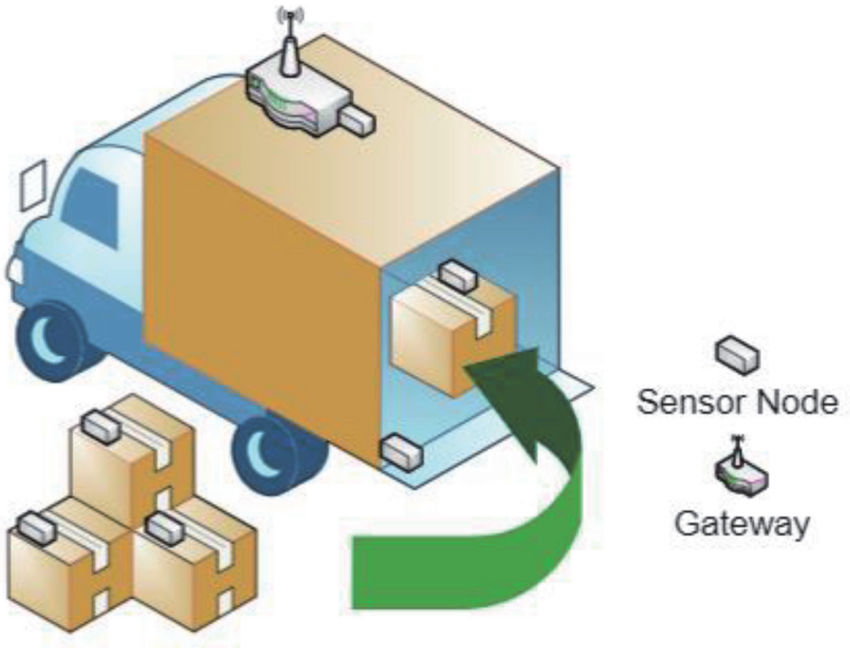

Figure 9.
Wireless sensor network for logistics.

wireless sensor network nodes are connected to goods (mostly food because of their perishable nature). The goods are loaded from a storehouse or warehouse to a good carrier vehicle, in which their nodes need to be self-organize and form a network of nodes, which can forward information of the goods' from one state to the outside world using a gateway (e.g. a telematics unit).

Logistics benefits clearly from Wireless Sensor Networks. However, the requirements of logistics for applicable WSNs are challenging.

2. **Environmental monitoring**

Simple computations and to send/receive data performance done by the sensor nodes. These nodes are small in size and are embedded into devices. Data collection is the typical usage where data collected from the surrounding environment via sensors. Environment monitoring has become an important field of control and protection, providing real-time systems and control communication with the physical world. During data collection sensor nodes

- Monitor and manage air quality,
- Monitor and manage conditions of traffic,
- Monitor and manage weather situations.

Characteristics of an environmental monitoring system

- Autonomy. Batteries must be able to power the weather stations during the whole deployment.
- Reliability. The network has to perform simple and predictable operations, to prevent unexpected crashes.

- Robustness. The network must account for a lot of problems such as poor radio connectivity (e.g., in case of snow fall) or hardware failures.

- Flexibility. One must be able to quickly add, move, or remove stations at any time depending on the needs of the applications.

3. **Industrial supervision**

   The advances in wireless communication, microelectronics, digital electronics, and highly integrated electronics and the increasing need for more efficient controlled electric systems make the development of monitoring and supervisory control tools the object of study of many researchers.

4. **Intelligent buildings**

   Wireless Sensor Networks (WSN) has become cardinal towards the implementation of smart homes, and they are proved to be a permitting technology for assisted living. WSNs are deemed appropriate for placement in home environments for diverse applications.

5. **Military applications**

   WSNs consist of a large number of small sensor nodes. Costing of small nodes is also less expensive. In military operations, there is always a threat or security challenges of being attacked by enemies. So if regular use of small nodes which is less expensive help to reduce the loss.

Figure 10 shows wireless sensor networks for military application. This application provides suitable sensors which can be used in top secret missions. These sensors can detect, identify and classify threads based on the count, number, whether it is armored vehicles or men in foot, type and amount of weapons they carry, etc., can be detected in advance. This application provides reliable real time war pictures and better situational awareness.

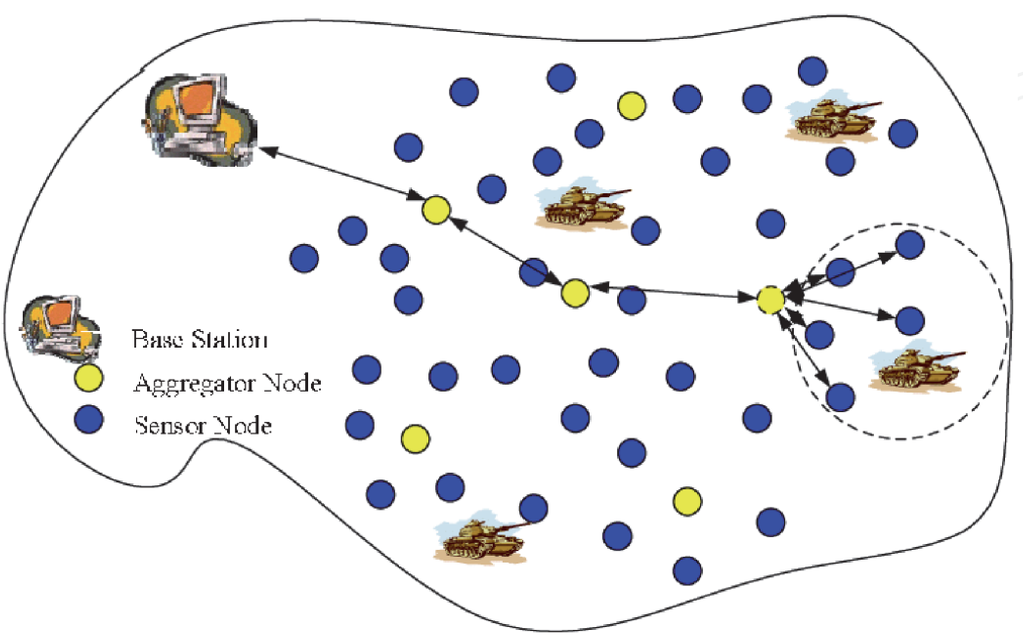

Figure 10.
Wireless sensor network for military application.

13. Conclusion

- Each such sensor network node typically has many parts: a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting.
- A sensor node might vary in size and size can be a size of a grain of dust.
- Sensor collects the analog data from the physical world and an ADC converts this data to digital data.
- When a large number of sensor nodes are deployed in a large area to cooperatively monitor a physical environment, the networking of these sensor node is equally important
- In flat architecture, the base station sends commands to all the sensor nodes.
- In hierarchical architecture, a group of sensor nodes are formed as a cluster and the sensor nodes transmit data to corresponding cluster heads.
- Wireless sensor network mainly consists of sensor nodes. A wireless sensor network consists of many different components.
- The static parts would be connected to the constant power supply, so that wireless parts can use low power to communicate to them and also nodes can go in the standby mode from time to time.
- A dynamic maintenance approach works as an 'on-the-fly'-based triggering technique that creates a new topology when the current one is no longer optimal.
- MANET stands for Mobile ad-hoc Network also called as wireless ad hoc network or ad hoc wireless network that usually has a routable networking environment on top of a Link Layer ad hoc network.
- The key to achieving a longer lifetime for WSN is to design wireless sensor networks that minimize power consumption of wireless sensor devices, hence the name "low power".
- Challenges in wireless sensor node in various ways for an application.
- The major applications of WSNs
- The goods are loaded from a warehouse to a freight vehicle.
- Their typical usage is to gather information about their environment via sensors, to potentially pre-process these data, and to finally transmit them.
- Characteristics of an environmental monitoring system

Author details

Bhargavi Dalal[1*] and Sampada Kukarni[2]

1 Shah and Anchor Kutchhi Engineering College, Mumbai, India

2 Modern College of Engineering, Pune, India

*Address all correspondence to: bhargavi.dalal@sakec.ac.in

IntechOpen

References

[1] http://www.wsn Wikipedia/google.com

[2] Deepika, Prof. S. Niranjan" Wireless Sensor Networks" **International Journal of Engineering Research & Technology (IJERT), ISSN: 2278–0181, Published by, www.ijert.org NCETEMS-2015 Conference Proceedings**

[3] Maarten van Steen1 · Andrew S. Tanenbaum2," A brief introduction to distributed systems" Computing (2016) 98:967–1009 DOI 10.1007/s00607-016-0508-7.

[4] https://en.wikipedia.org/wiki/Wireless_sensor_network

[5] David Kohanbash*, Abhinav Valada, George Kantor, "Base Station Design and Architecture for Wireless Sensor Networks", Carnegie Mellon University Robotics Institute, 5000 Forbes Ave, Pittsburgh, PA, 15213 USA.

[6] https://www.electronicshub.org/wireless-sensor-networks-wsn/ "Basics of Wireless Sensor Networks (WSN) | Classification, Topologies, Applications", March 2019.

[7] https://www.geeksforgeeks.org/introduction-of-mobile-ad-hoc-network-manet/

[8] Carlos F. García-Hernández†, Pablo H. Ibargüengoytia-González†, Joaquín García-Hernández†, and Jesús A. Pérez-Díaz," Wireless Sensor Networks and Applications: a Survey", IJCSNS International Journal of Computer Science and Network Security, VOL.7 No.3, March 2007.

[9] Mrunal Khedkar, Dr. G.M. Asutkar," Energy Optimisation in Wireless Sensor Network for Video Data Transmission", 2018 IEEE Global Conference on Wireless Computing and Networking (GCWCN)

[10] Muammad R amed,Xu Huang, Dharmandra Sharma,and Hogyan cui, "Wireless Sensor Network: Characteristics and Architectuer", International Journal of Information technology and communication Engineering Vol:6,No:12,2012.