CHAPTER 1

INTRODUCTION TO WIRELESS SENSOR NETWORKS

Ever since the appearance of the first computers at the beginning of last century, the evolution of computer systems was marked by milestones of miniaturization. Indeed, the appearance of the transistor, followed by micro-chip, personal computers, laptop computers and handheld are so many revolutions that have marked this process of growth. At the turn of the century, some mobile phones are more powerful than desktops sold in late 1980. Now, electronic small systems are ubiquitous in our environment. In contrast to this decrease in quest of the component size, letting alone of so-called intelligent machines, the evolution of computing (Barton & Lehre, 2016) required for its part, increased with the decreased device sizes. Now these wireless devices are used for so many peculiar applications (Arampatzis et al, 2005) giving various advantages and benefits (Tarasewich, 2003).

Recent advances in the field of microelectronics and wireless communications technologies have created a combination of embedded systems and distributed systems that have formed the Wireless Sensor Networks (WSNs). The sensors appear as miniaturized autonomous systems, equipped with a processor (microcontroller) Board, have (transceiver) radio, internal memory and a battery (Kuncoro, 2015). Network nodes have the mission to gather data and transmit them to a specific node named Base Station (BS) as illustrated in the figure 1.1.

The attractive features of these systems (low cost of development, autonomy of operation, easy installation, etc.) have paved the way for a multitude of applications constituting the privileged seats of their deployment. Among the potential applications of WSNs, those using sensors are significant because they relate to particularly sensitive areas (monitoring, micro-cameras that can transmit images from inside the human body, in a video sector strategic or difficult to access, etc.).

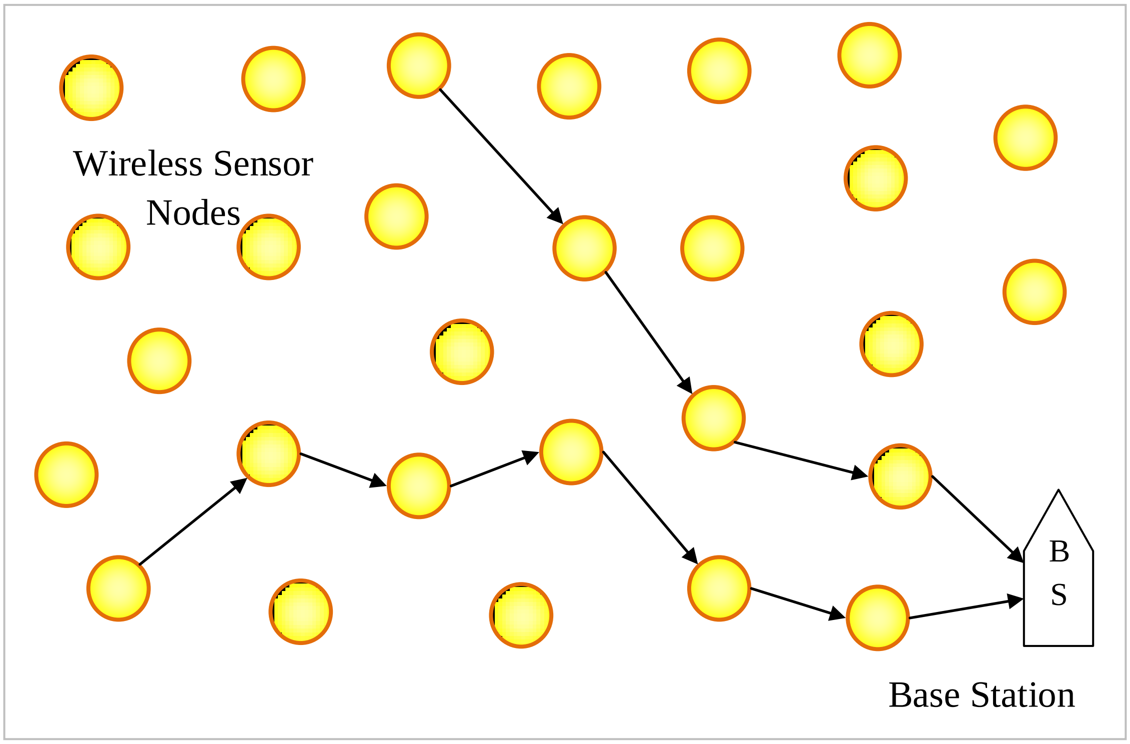

Figure 1.1 Wireless Sensor Network

The significant progress in electronic sensing enabled a significant improvement in sensors for a decade. Indeed, the first sensors, more consist size, were often placed close to the event to receive, often requiring complex technical differentiation of targets to be observed from the surrounding noise (Arora et al, 2004). Now, has WSN is composed of a large number of small nodes, which are deployed at the core of the phenomenon to be observed, otherwise a very short distance. The positions of the sensors do not require prior study and need not be pre-determined. This allows such a chaotic deployment in inaccessible or devastated areas (Low et al, 2005).

However, many obstacles inherent in their specificities must be overcome before they can reach technical maturity. Among these obstacles, the resource limitation problem (energy, computing power, memory, transmission rate, etc.) is acute, because of the constraints of miniaturization and manufacturing cost, and must be solved so effective and in accordance with the particular characteristics of WSNs. Fortunately, technological advances in microelectronics have allowed the development of embedded micro-cameras in virtually any existing electronic devices (cell phones, laptops, PDAs, WSNs), without significantly increasing the cost of equipment (cost energy, price, weight, shape, etc.).

Two major classes of networks deployment of WSNs raises a number of conceptual issues such as self-organization, adaptability or the dynamics of the network topology (Mills, 2007). Among the different characteristics of a WSN, mobility of nodes in time and in space divides the networks into two great classes. While solutions are based on knowledge of the geographical coordinates are simply attainable in a context of static WSN, they become unfeasible or expensive energy in the presence of high mobility. In addition, some collaborative basis could be enforced by the participating nodes in the communication. For this, the efficiency of a particular solution depends on the underlying routing protocol, anonymity nodes, or the displacement model thereof.

While a large number of applications implements WSN, they have several inherent limitations to consider in their design, whether static or mobile. In addition to the fact that a sensor suffers from local limitations, such as low computing power, limited reserves of energy and a reduced bandwidth communication, it is necessary to take account of the global aspects of the system as well.

1.1 Overview of WSN

With the integration of sensors in the embedded systems, the enlargement of the range of applications for the wireless sensor networks (WSNs) became possible. Over the past few years, a new field of research has attracted a few groups of researchers, motivated by this new challenge: it is the Networks of Sensors. Indeed, some applications need to identify with accuracy the objects that pass through the field are monitored by the WSN. The multimedia information represents an indispensable medium for the validation of several applications such as the identification, localization and tracking of objects. However, the multimedia processing is confronted with the problem of exhaustive consumption of energy that reveals the need for a specific solution for the nodes in a network of sensors multimedia.

WSNs are part of ad hoc networks (or MANET for Mobile Ad hoc Network). In this type of networks, the nodes to organize only and a fully decentralized manner, thus forming an autonomous network and dynamic is not based on any wired infrastructure. The hosts on the network can be fixed or mobile depending on the nature of the application.

The sensor nodes or hosts are scattered randomly on the entire area to check/monitor. The BS, generally known as sink and located at the end of the area to monitor, is responsible to collect the information from the sensors and the transfer to a terminal of treatment, where the analysis of these data takes place. In this case, when an event occurs (sharp variation of temperature or pressure, for example), an alert is routed through a communication multi-hops to the sink. It is therefore for the collection of information in response to an event. There are two other methods to retrieve data from the network: collection at the request and periodic collection. The first method is to issue a request by the sink node to all the nodes of the network (broadcast) for that they date back their latest reports to the sinks. With regard to the periodic collection, the sensors take measurements (temperature, pressure, etc.) in regular intervals of time to the sink/BS.

Various platforms sensor networks are designed and can be grouped into low-end and high-end. The first class is characterized by limited capacity in terms of information processing and the storage. In this case, a large number of sensors must be deployed. From an architectural perspective, the type of ‘high-end’ platform is based on more efficient components. At the end of the heterogeneity of platforms sensor networks, standards were developed (Ahamed, 2009).

- IEEE 802.15.4 offers three bands of communication.
- The overall 2.4 MHZ band, band 915 MHz reserved for America and that of 868 MHz reserved for Europe.
- This standard defines the protocols of the physical layer and the MAC (Medium Access Control). It adapts good for star topology networks, mesh, and cluster tree.
- IEEE 802.15.4 allows communications at a distance of 10-100 m with a flow rate of 20-250 Kbps.

1.2 Working Strategy of a WSN

In parallel, monitoring applications, protection and observation of our environment have increased in recent years, both in the medical and ecological or military. Unfortunately, human intervention is not feasible in all investigative areas. The 2000s then saw the birth of “smart dust” set of hardware platforms miniaturized coupled with a data acquisition module for capturing and collecting gold stimuli events from the local environment of the sensor. The low technological possibilities of a single sensor will not allow it to have its own utility, aim the networking of many of these opens up opportunities for progress and exciting operation.

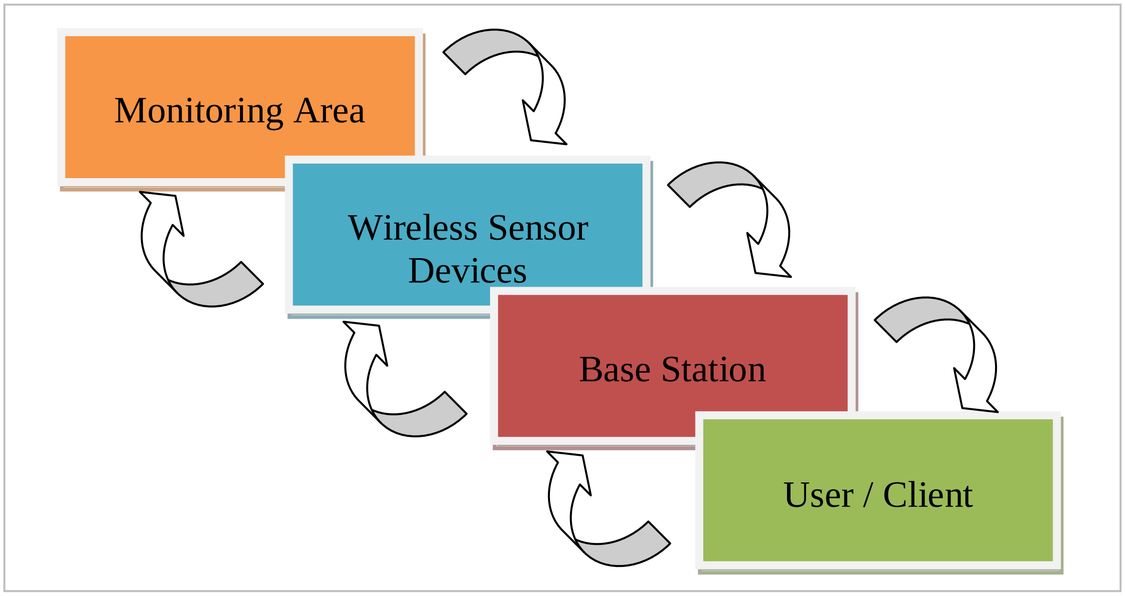

Figure 1.2 Wireless Sensor Network – General Working Strategy

Based on the example shown in the figure 1.2, it is possible to understand the various components of the WSN. A monitoring area contains the wireless sensor devices reporting to a BS from which a user / client can access useful information for decision making in the application used.

The interest of the communities from research and industry for these Wireless Sensor Networks (WSNs) increased by the potential reliability, accuracy, flexibility, low cost and ease of deployment of these systems. The characteristics of WSNs possible are considering a large number of observation distributed applications in space. These can be deployed in many contexts:

- Pollution,
- Flooding,

- Observation of the natural environment,
- Ecosystem monitoring,
- Military operations,
- Remote monitoring (monitoring of birds niches, plant growth, battlefield, enemy detection, etc)
- Biomedical and medical supervision (cancer detection, artificial retina, glucose, diabetes, etc).

Spontaneity, adaptability and network topology dynamicity in the deployment of WSNs raise many questions which are still outstanding (Bachir et al, 2010). One of the binding limitations of these networks is the low energy resource sensors mainly due to their size and minimalist wired independence. This constraint should be considered the primary concern in the design and deployment of WSNs.

1.3 Architecture of a WSN

There are many components in a WSN including the Microcontroller (Callaway, 2003). Some of these components are discussed here (Munir et al, 2007).

- **Microcontroller**

The Microcontroller represents the heart of the node of the WSN. It receives the data from the sensors, treats these data, decides when and where the send and manages control of actuators (if they exist). The Microcontroller also receives packets from the neighboring nodes, the analysis and responds to these messages, if necessary. Other more complex tasks are entrusted to the Microcontroller such as memory management, the management of the energy (migrate from active mode to standby or hibernate mode and vice versa), scheduling of the tasks, management of devices, etc. The existing platforms of wsns use a wide variety of microcontrollers to different architectures.

- **Analog-digital-converter (CAN)**

An analogue/digital converter (CAN) is necessary to convert the analog signals from sensors to digital values exploitable by the microcontroller. The choice of a CAN depends on the needs of the user and the constraints imposed by the application (speed of conversion, the cost of the converter, energy consumed by conversion, surface occupied by the CAN, etc.). The benefits in terms of reduction of energy of asynchronous circuits compared to synchronous circuits have pushed researchers to design of asynchronous CAN (A asynchronous CAN takes a sample only when the physical magnitude varies more of a quantum of predefined amplitude). The Asynchronous technology however, suffers at the present time of a lack of maturity that may explain the scarcity of asynchronous CAN marketed (Karl & Willig, 2007).

- **Real-time clock**

The WSNs often use a piezoelectric-quartz in order to maintain the time information in the system. The communication protocols are using the real-time clock for having a common time between nodes (Synchronize the hosts between them). This clock can also be used in the system software as a *timer* to wake up the microcontroller to specific dates.

As this hardware part is permanently ACTIVE, its energy consumption should therefore be low to have a long life of the node. The typical consumption of clocks Real Time is of a few hundreds of nano-amps, which makes its consumption comparable to the consumption in Eve of other functional blocks of the node.

- **Wireless communications module**

The wireless communications module can be a transmitter/receiver optical or ultrasound, but generally it is a radio transmitter/receiver which mainly uses one of the 3 bands ISM (Industrial, Scientific and Medical): The 400 MHz band, the 900 MHz band and the band of 2.4 GHz. Several research works have helped to reduce the consumption of the radio module in order to extend the life of the sensor node. Most of these studies have referred to the reduction of the phenomenon of the passive listening or listening useless; but despite this, the consumption due to this phenomenon remains important (consumption during passive listening is of the same order of magnitude as that due to the emission and reception of data).

As the transceiver radio is the component most vital in determining the energy in a node of WSN, it is quite clear that the fact of reducing the amount of data to transmit allows you to save energy in an effective manner. The most obvious solution is the compression of data, but sometimes the data compression techniques used has an energy cost very high, especially when it comes to compress the images or videos. It must therefore develop compression algorithms that are energy efficient and which have a good report.

- **Localization System**

A sensor is only useful if a information relative to its geographic location is provided. The Global Positioning System (GPS) is the system of locating the most known and used at the global level. The general principle of these technologies is described as follows: when a localization module of request its position, each satellite communicates to the node’s coordinates and the distance that separates it from another node.

- **Sensors/actuators**

The detection unit contains one or several sensors embedded on the node. These sensors are transforming the physical quantities observed (pressure, temperature, humidity, speed, movement, etc.) in size electric (electrical voltage, intensity, train of pulses, etc.). Some platforms of networks of sensors are composed of nodes equipped with actuators. An actuator allows you to convert entry energy (generally an electrical energy in the case of WSNs) in energy of output (usually a electrical signal of Command) usable for order or check a process (example trigger an alarm after a fire).

- **Battery / energy recovery system**

The nodes have a battery of power supply as the main source of energy. Some platforms use systems for the recovery of energy from the environment. of our days, the use of the materials-piezo is the means of recovery of the energy the most adequate for the nodes of WSNs.

1.4 Characteristics of a WSN

Some of the characteristics of the wireless sensor networks, regardless of the type of the application and platform used (Buratti et al, 2009).

- **Self-organization**

The self-organization makes reference to the organization of the hosts in the network without interaction with an external entity and without centralized control. Local interactions between the sensor nodes enable the network to find and maintain a structure that responds effectively to the needs of the application. A local change must not only weakly affect the overall structure.

- **Fault Tolerance**

The failure of one or a few nodes must not lead to the failure of the entire network. The CWHN must be able to operate partially and with reduced performance instead of falling completely fails.

- **Collaboration**

Sometimes a node is unable to decide alone if an event occurred or not. It must therefore cooperate with the neighboring nodes to take the right decision.

- **Flexibility**

The sensor nodes must be able to adapt quickly and effectively on the basis of the situation of the network (to update the routing table as a result of the failure of a node, decrease the QoS criterion when the available energy becomes critical, etc.).

- **QoS: (Quality of Service)**

There is talk of QoS when one wishes to achieve a better behavior of the network. The parameters that influence the QoS criterion are the following: the rate of packet loss, jitter (difference of time of transfer of end-to-end between packets of the same data stream), the flow (in k bits/sec) and attenuation of the signal.

The attenuation of the signal is strongly linked to the distance which separates the nodes. This parameter does not affect too much the quality of service since the WSNs most often use of communications multi-hop.

- **Scalability**

The monitoring of a phenomenon may require the deployment of a number of nodes which is of the order of several hundreds or even thousands of sensors. The network must be able to exploit the nature highly dense of some applications.

1.5 Topologies in a WSN

There are basically two major topologies in the WSN that are not just physically different from each other in the arrangements but have different functional and application based significances (Liu, 2012).

1.5.1 Flat Topology

An arrangement with all the nodes performing the same function to operate as a WSN is called as the flat topology. Figure 1.3 illustrates the working of the flat WSN where each of the nodes consecutively transmits captured/sensed information until it reaches the BS.

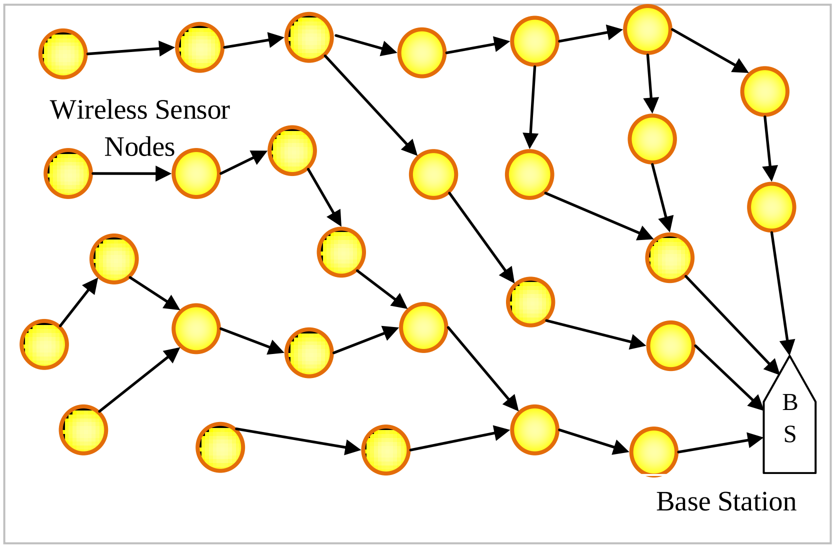

Figure 1.3 Flat topology of a WSN

1.5.2 Hierarchical Topology

Hierarchical topology is the arrangement where the nodes are different from each other by means of the tasks they perform inside a WSN. Some of these nodes are group heads / cluster heads and have greater responsibility than the others (Singh et al, 2010). Therefore it is very advantageous to use the hierarchical topologies in terms of segregating the tasks and distribution purposes to increase the efficiency. An illustration of the hierarchical topology is given in the figure 1.4.

Among the main advantages of hierarchical structure, there are simplicity and clarity of reporting relationships within each system's service: every node knows its Cluster head to which it reports and held to commitments. There is also the development of a discipline or protocol, through the principle of the unity of the protocol management: this allows the productivity of WSNs to focus on their core application, to maximize performance.

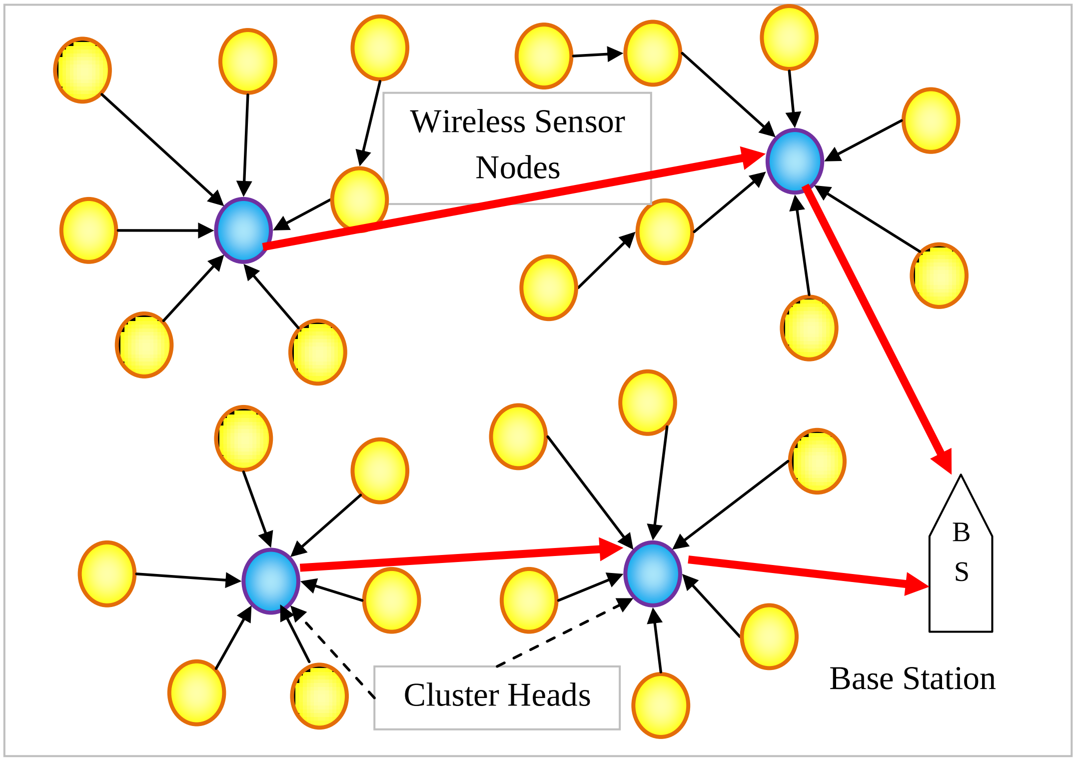

Figure 1.4 Hierarchical Topology in a WSN

1.6 Applications of WSN

There are a number of applications in the WSN (Arampatzis, 2005); some of the applications are discussed here.

- **Monitoring of industrial machines**

The idea is to attach sensors on places of difficult access to detect events that indicate the need for maintenance (vibration, smoke, noise and noise pollution, etc.).

- **Detection of fires**

The sensor nodes, deployed in a forest for example in figure 1.5, collectively produce a "temperature map" of the entire surface area covered. For this kind of applications, the cost of the sensors must be low enough to be able to deploy a large number of nodes and cover a greater surface area.

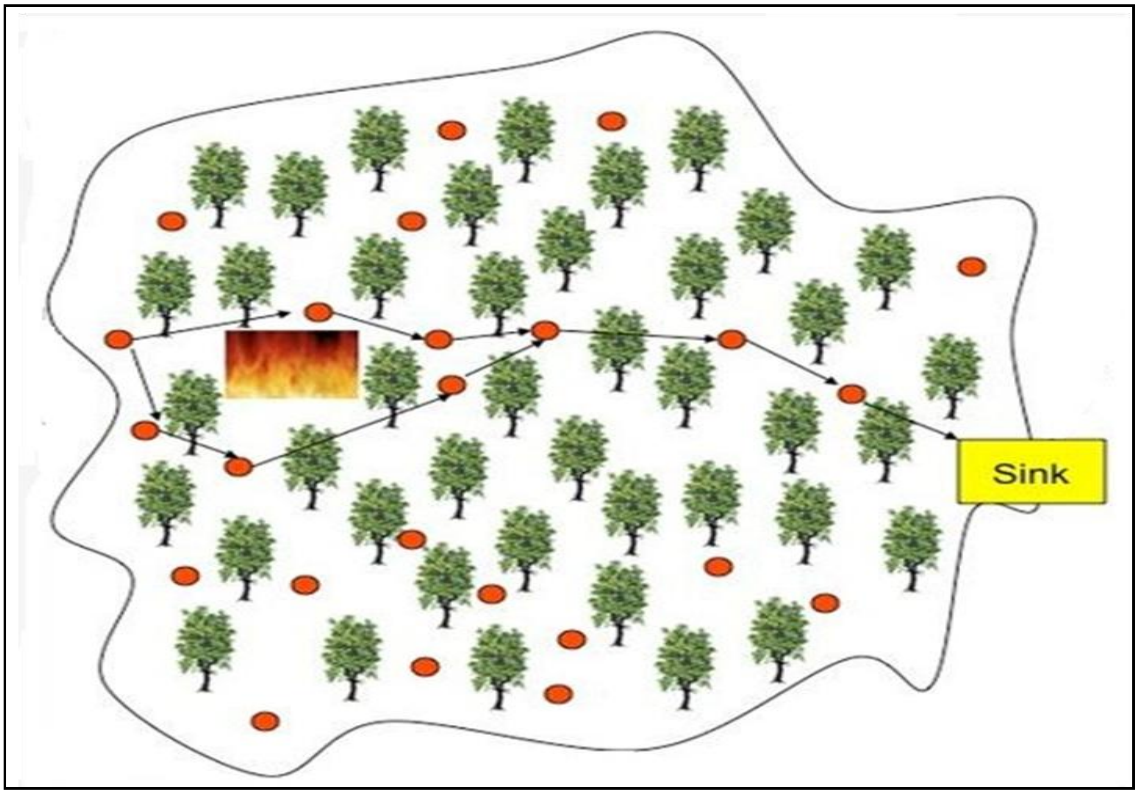

Figure 1.5 Forest fire detection

- **Construction Work**

The installation of a WSN inside a building allows addressing effectively the problem of loss of energy (bad ventilation, bad use of air conditioning, etc.). The sensor nodes are generally used for a better control of the temperature and humidity, which increases the level of comfort of the inhabitants. WSNs are deployed also in areas of high seismic activity to check the holding to mechanical constraints. Figure 1.6 shows the use of sensors in the construction field.

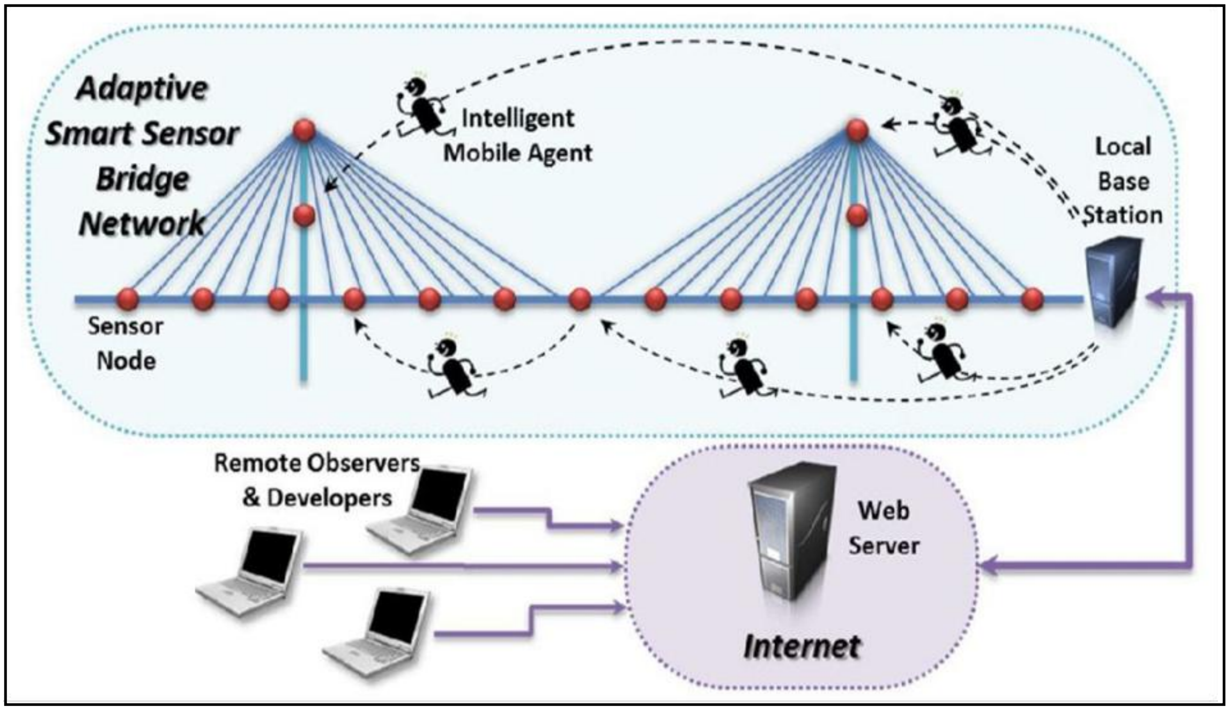

Figure 1.6 Construction work

- **Military applications**

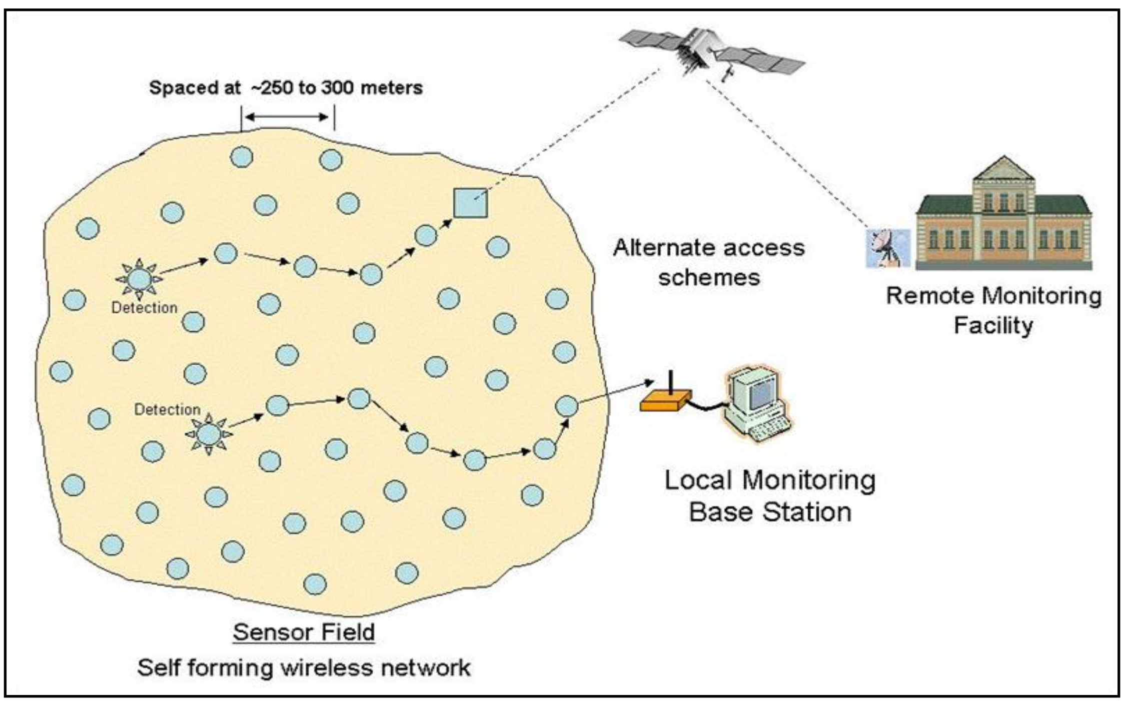

Figure 1.7 Military application

The first potential applications of wireless sensor networks have concerned the military field. The idea is to deploy nanoscopiques nodes, and therefore invisible, on a field of battle to monitor the movements of enemies. The example military application is shown in figure 1.7.

- **Medical Applications**

WSNs can be used to monitor and control the vital functions of a human being. Of micro-sensors swallowed or implanted under the skin can treat certain diseases without recourse to the surgery (early detection of cancer, implantation of a artificial retina to correct the view, etc.). The use of sensor in the medical industry is illustrated in figure 1.8.

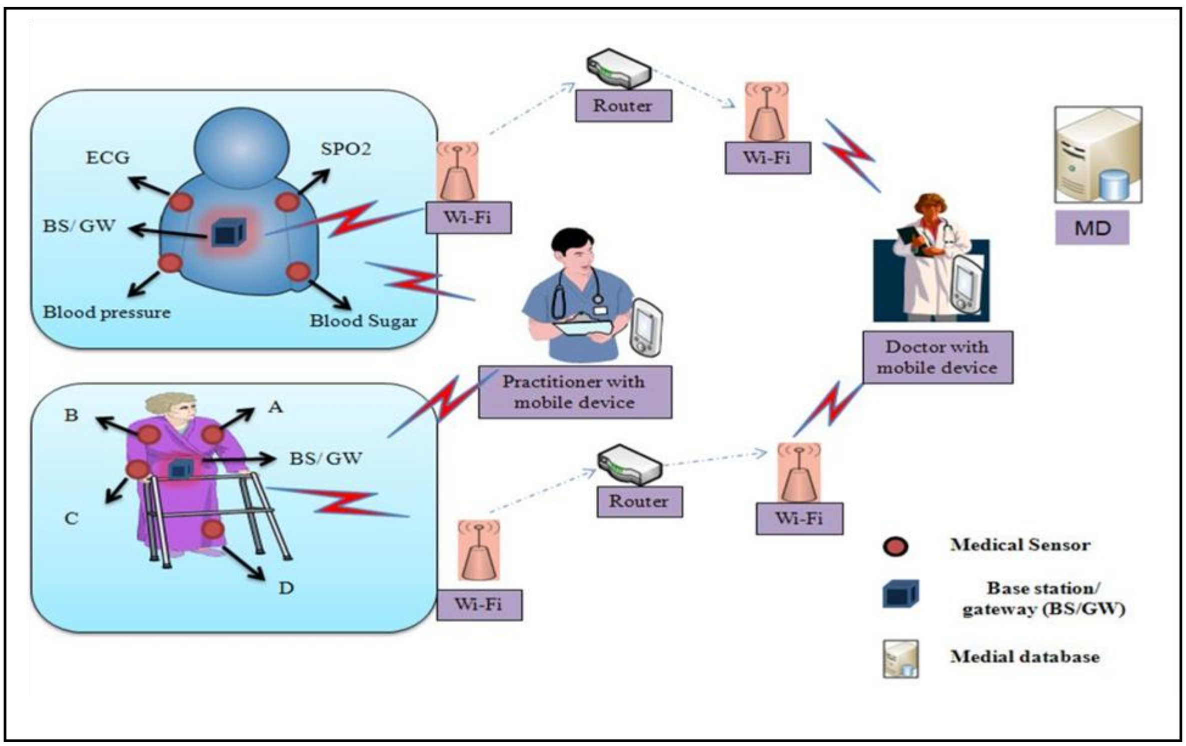

Figure 1.8 Medical application

1.7 Objectives of Research

The main aim of this research work is to analyze and provide suitable solutions to design protocols for Dynamic Trust Management Scheme for Cluster based Hierarchical WSN.

- To propose the Trust based Energy Efficient Scheme for Hierarchical Clustering in WSN.
- To design the Hierarchical Trust based Efficient Cluster Head Selection in WSN.
- To design an Efficient Data Collection Scheme based on Trust Evaluation in Large Scale WSNs.

1.8 Motivation of Research

Although there are various advantages in the hierarchical routing, there is a strong reason why attackers are more interested in such WSN systems. The group heads/ cluster heads are more vulnerable to attacks since they hold responsible positions inside the WSN.

Expensive cryptographic systems cannot be afforded by all the small and medium scale industries while providing security. Keeping this in mind, the research has been carried out to provide novel methods aiming at solving internal attacks and providing trust in hierarchical WSN.

1.9 Problem Description

In most recent years, various security mechanisms, e.g., cryptography, authentication, confidentiality and message integrity, have been proposed to avoid security threats such as eavesdropping, message replay and fabrication of messages. However, these approaches still suffer from many security vulnerabilities, such as node capture attacks and denial-of-service attacks.

The traditional security mechanisms can resist external attacks, but cannot solve internal attacks effectively which are caused by the captured nodes. Hence, the reliable security mechanism is more important in WSNs. This research work mainly focuses on performance analysis and design mechanisms to Trust Management Scheme for Cluster based Hierarchical WSNs.

1.10 Organization of the Thesis

Chapter 1 gives an Introduction to the WSNs, various issues related to routing in such networks, significance and applications of the same.

Chapter 2 provides a detailed literature survey pertaining to the research done in the area of WSNs.

Chapter 3 presents the Trust Based Cluster Head Selection Algorithm for Wireless Sensor Network.

Chapter 4 presents the Design of Trust Based Energy Efficient Scheme for Hierarchical Clustering in Wireless Sensor Networks.

Chapter 5 presents the Design of Hierarchical Trust Based Efficient Cluster Head Selection in WSN (HTECH).

Chapter 6 designs an Efficient Data Collection Scheme Based on Trust Evaluation in Large Scale Wireless Sensor Networks.

Chapter 7 presents the comparative Analysis of Results and Discussion.

Chapter 8 provides the Conclusion of research work and the future scope.

1.11 Summary

An account of the basic architecture and working of the WSN is presented in this chapter. Also the various challenges and issues with regard to the topological arrangement in the WSN and their advantages are also presented. The problem identified is the lack of security in the hierarchical topology, and thereby this is considered as the main focus for further research. The following chapter gives a detailed idea about the various methods used in the WSN.