IoT Technologies: Wireless Sensor Networks

Patrick Stephen Eteng
Electronic Engineering
University of Applied Science Hamm-Lippstadt
Lippstadt, Germany
stephen-eteng.patrick@stud.hshl.de

***Abstract*—In recent times, Internet of things (IoT) has been a significant source for technological solutions in many industries, that enable the combination of real-world data and services into the current information networking technologies. On the other hand, the deployment of Wireless Sensor Network technology with reference to Internet of things has been deployed in an exceedingly big selection of applications, this can be because sensors are getting smaller in size and the cost of production is comparatively cheap. This research paper is geared towards presenting a review on wireless sensor networks, highlighting the different types of sensor networks, topology, challenges, various applications, as well as the Advantages.**

***Index Terms*—Internet of Things, Sensor Node, WSN Topology, Security.**

I. Introduction

The emergence of wireless networking technologies has had a huge influence in our daily lives and its totally remarkable. The Internet of Things (IoT) as we are already aware of is one of the most rapidly emerging future technologies. By using IoT, several devices may be linked in the physical environment, thereby impacting on our daily lives. As a result, the need for communications at all times and in all places is fast growing, particularly in domains with considerable activity. The Internet of Things (IoT) is a collection of physical devices ranging from everyday devices like laptops, mobile devices, televisions, not excluding other home appliances to devices used for high-end calculation and processing in industries, like temperature measurements, whether mapping, fluid density control, and so on. All these are some of the devices that have been beneficial to humanity in a variety of ways. By embedding sensors in these devices, they would be capable of communicating as a network and would in turn make them more responsible and intelligent. And this can be achieved by combining the Internet of Things with Wireless Sensor Networks (WSN). The term ”wireless” has become a generic and all-encompassing phrase for communications in which electromagnetic waves are employed to transfer data along a portion or the complete communication line [1]. WSNs are made up of a large number of dispersed sensor nodes, each of which has a sensor that can detect and monitor a variety of physical phenomena or parameters such as light, heat, pressure, humidity, temperature, density, and so on [2]. The data would be collected and processed by these sensors with the aid of a centralized base station. WSNs are considered as a new information collecting technology for constructing an information and communication system that would considerably increase infrastructure system dependability and efficiency. We are now in the era of digitizing the entire planet, thus we need devices that can interact with each other to reduce the complexity of communication networks to the level of human understanding. The Internet of Things is one such field that assists us in the global construction of communication networks. People can create an efficient digital network that can connect with each other by adopting IoT technology. We have been able to establish a network of senses using the technology that has been created thus far, which are known as wireless sensor networks. We can utilize the WSN to create a network of sensors that can gather data, process it, and use the information to improve the network.

II. WSN and Sensor Node

A wireless sensor network is a network composed of distributed autonomous sensor nodes that monitors physical and environmental conditions such as temperature, humidity, pressure, sound, vibrations, and so on [3]. These conditions are either communicated directly to the base station or to neighbor nodes after being sensed by the sensor. Figure 1 shows the semantic of a Wireless sensor network. WSNs are often devoid of infrastructure. An unstructured network is made up of several sensor nodes that are randomly deployed to monitor the environment without any infrastructure. Sensor nodes in unstructured networks can self-organize. Seniors are assigned to structured networks according to a predetermined strategy. Components of sensor nodes are organized into the following subunits in Figure 2: communication subunit (radio transceiver antenna), sensing subunit (sensor), computing subunit (microprocessor with memory), and power unit (battery) [4]. The sensor, which is a transducer, detects and measures natural occurring events in analog form (environmental and physical conditions) before converting them to an electrical signal using an ADC. The type of sensor to use during design is determined by the physical state to be assessed, such as a light sensor, thermal sensor, magnetic sensor, vibration sensor, chemical sensor, seismic sensor, acoustic sensor, or bio-sensor. The transformed electrical signal is sent into a microprocessor (controller), which uses signal processing to perform the appropriate algorithmic operations on the digital signal. The signal is sent from the transmitting antenna to surrounding nodes or to a base station, which determines the optimum delivery path. This, however, is dependent on the sort of network topology. The battery, as a crucial component, ensures that sensor nodes continue to function by delivering constant power. This is because a sensor that isn't powered is basically dead. The battery's capacity and size impact the sensor's life cycle, particularly for sensors in distant places with limited power. The problem of sensor batteries presents a challenge to successful sensor operation and long-term sensor sustainability. WSN research is still ongoing for improvement as a result of its obvious benefits. WSN technology, on the other hand, has a number of benefits over traditional networking technologies, including reduced costs, scalability, dependability, accuracy, flexibility, and ease of deployment, which make it suitable for a variety of applications [5]. Sensors are getting smaller, smarter, and cheaper as technology advances, and billions of wireless sensors are put in specific points for a variety of purposes.

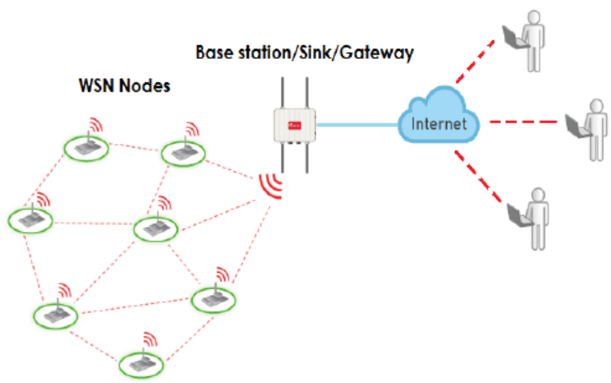

Fig. 1. Wireless Sensor Network [6]

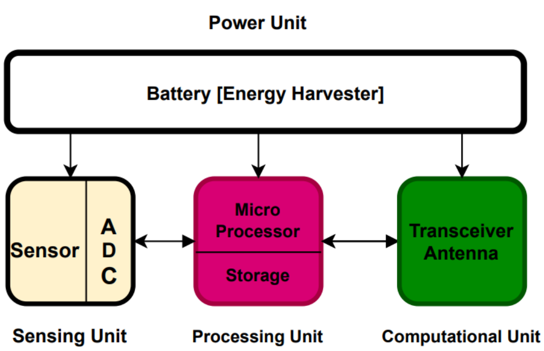

Fig. 2. Hardware structure of a WSN sensor node

III. Characteristics of WSN

The best possible qualities are required for successful wireless sensor network implementation. A better network entails many concessions, yet better quality comes at a higher cost. The following are the characteristics of WSN:

A. Robustness

In terms of hard environmental conditions, it is resistant to failure. This guarantees improved coverage by allowing nodes to move around.

B. Scalability

Scalability to a large distribution scale.

C. Low Energy Consumption

D. Mobility of nodes

E. Flexibility

F. Low price

G. Reliability

H. Real-time transmission

I. Quality of service

The quality of service (QoS) of a sensor network is a measure of its ability to satisfy application-specific needs [7].

J. Simplicity in usage

These features are well-suited to a variety of applications. Even yet, there are several concerns and obstacles with wireless sensor networks. Improved key properties of these networks is one of the issues.

IV. Advantages of WSN

A. It is possible to set up a network without relying on fixed infrastructure

B. The cost of setting up a WSN is quite affordable

C. The use of a wireless communication medium is employed

D. WSN is ideal for inaccessible locations like as mountains, seas, rural areas, and dense woods

E. WSN is cability of adding new network devices at any given time

F. It is capable of monitoring from a central location

V. Challenges of WSN

Wireless sensor networks have a lot of potential since they will allow us to monitor and interact with the physical world from a distance. Sensors have the capacity to capture a large volume of previously unidentified data. To fully realize the capabilities of sensor networks, we must first tackle the networks' unique limits and the resultant technical challenges. Although data fusion necessitates synchronization of nodes, synchronization algorithms for sensor networks must take into account the following characteristics. A number of constraints must be addressed in order for WSNs to become absolutely prevalent.

A. Energy

Because sensor nodes rely on batteries for their longevity, this is a significant problem. The majority of the sensors are in inaccessible locations, with a few in distant locations with epileptic supply of power. Also because sensors are intended to function 24 hours a day, this is certainly a limitation for their usability. In conclusion, it is very difficult to charge sensors once they've been discharged.

B. Transmission media

WSNs are prone to fading, attenuation, interference, and a high error rate since they are connected through wireless media.

C. Limited Bandwidth

Message exchanges between sensors are directly affected by bandwidth limitations, and synchronization is impossible without message exchanges. Sensor nodes that communicate with one another often have limited bandwidth.

D. Fault tolerance

Sensors placed in key locations may experience hardware or software issues, or fail due to a lack of power or environmental interference. The routing protocol must be able to find these nodes and support the construction of new links.

E. Scalability

As the network size increases, the wireless sensor network must be able to handle additional nodes.

F. Cost of deployment

The cost of acquiring a sensor node is quite expensive. As a result, installing hundreds or thousands of nodes will result in a cost multiplier impact, not only in terms of purchasing but also in terms of maintenance.

G. Time synchronization

A node must have the same timing as the sending node in order to receive information from another node. Due to variations in time, packets transmitted could be delayed or lost.

H. Design Constraints

Wireless sensor design's main objective is to make devices that are smaller, less expensive, and more efficient. The design of sensor nodes and wireless sensor networks might be affected by a range of other issues. With constrained design models, WSN has issues in both software and hardware design.

I. Security

One of the difficulties with WSNs is meeting high security requirements while working with limited resources. A large number of wireless sensor networks collect sensitive data. Sensor nodes that are operated remotely and unchecked are more vulnerable to malicious attacks. Node authentication and data privacy are two security criteria in WSNs. The deployment sensors must pass a node authentication examination by their respective management nodes or cluster heads to detect both trustworthy and unreliable nodes from a security standpoint, and unauthorized nodes can be separated from WSNs during the node authentication method. As a result, new ways for key creation and distribution, as well as node authentication are required for sensor networks.

VI. Applications of WSN

A. Military Application

WSNs are an important part of military intelligence; they are used on the battlefield to keep track of enemy, as well as to identify all types of chemical, nuclear, and human assaults

B. Medical/Health Application

In acquiring biodata on patients and monitoring their progress, such as respiratory rate, blood pressure, and cardiac problems. It assists medical practitioners in diagnosing patients and assessing their progress. Some of these sensors are wearable, while others are integrated inside the device.

C. Home Monitoring

Sensors may be used to track human movement in buildings as well as in household appliances to provide a remote control

D. Agricultural Applications

WSNs have been used to farmers with a variety of tasks, including maintenance of wiring in challenging environments, irrigation mechanisation, which promotes more efficient water usage, and waste reduction

E. Environmental application

Sensors are used to track and investigate animal movement and behavior as well as investigate human movement. Also, it is used in checking for occurrences such as flood, landslide, detection of earthquake, forest fire detection, and so on

F. Area surveillance/monitoring

Sensors are used to monitor a specific mapped out region for a variety of purposes, including crime scenes, traffic offenders, fire disasters, oil deposit detection, etc.

G. Environmental/Earth Sensing

Sensors are being deployed to keep an eye on Earth for any potential earthquakes, volcanoes, air pollution, glaciers, and other natural disasters.

H. Industrial monitoring

Industrial plants, structures, and machinery are all monitored using sensors. WSNs are used by energy companies to monitor pipelines for leakages or defect.

VII. WSN Topology

The following are examples of wireless sensor network topology: point-to-point, star, tree, and mesh.

A. Point-point Topology

A point-to-point topology connects two nodes together. As shown in figure 3 below, the point-point topology sends messages to nodes through a single communication channel. It does not have a central hub. As a result, each node serves both as a node and as a client.

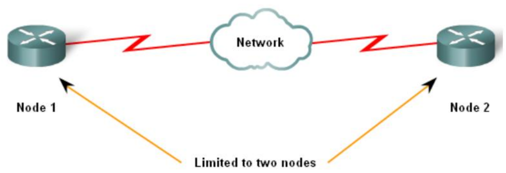

Fig. 3. Point-Point Network Topology [8]

B. Star Topology

Each node in a star topology connects directly to a gateway. Data must flow through the sink (gateway) before it can be routed to the target node in order for nodes to interact. The distant node and the gateway can communicate with each other with low latency. The gateway must be within the transmission range of all individual nodes since it depends on a single node to administer the network. Figure 4 below shows a star topology network. The ability to bring remote node power consumption to a bare minimum and easily under control is one of the benefits. The number of nodes that connect to the hub determines the network's size.

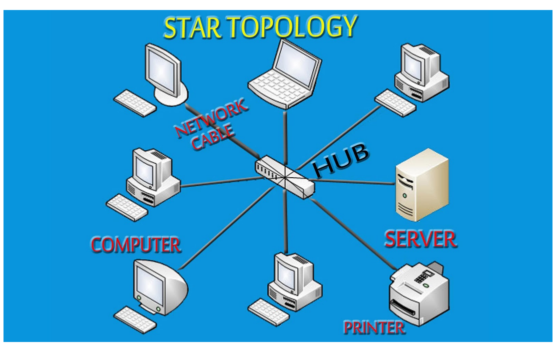

Fig. 4. Star Network Topology [9]

C. Tree Topology

Each node in a tree topology is connected to a node higher in the tree, and eventually to the gateway. The tree topology network is shown in figure 5 below. The benefit of this topology is that it allows for quick network expansion and error detection.

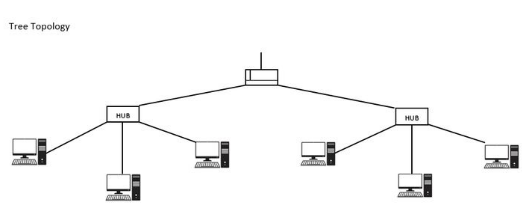

Fig. 5. Tree Network Topology [10]

D. Mesh Topology

Mesh topology allows clients to send data to one another and to go to their destination through several paths. Radio communication between nodes is required. If a node is out of range, data will be routed through an intermediary node. Figure 6 below shows a mesh network connection. One of the advantage of this mesh topology is that it allows for easy network fault isolation and detection, but the drawback is that the network is big and requires a significant investment. Bus topology, Circular topology, Ring topology, and Grid topology are examples of other topology [11].

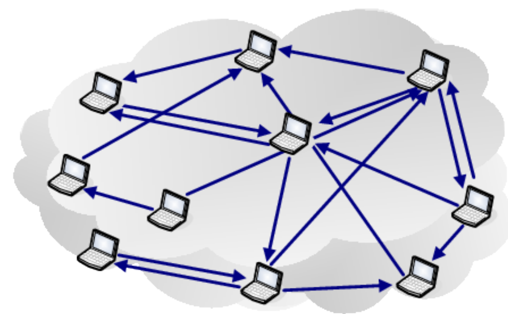

Fig. 6. Mesh Network Topology [12]

VIII. Types of WSN

The types of WSNs that are based on the environment are shown in figure 7 and also listed below.

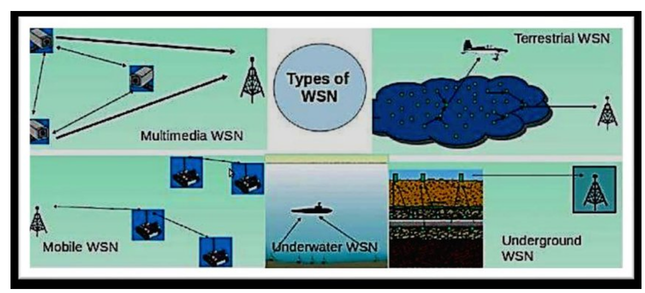

Fig. 7. Types Of WSN [13]

A. Terrestrial WSN

They are made up of a large number of sensor nodes that are randomly placed around a particular area, generally on land, in a pre-planned (structured) or ad hoc (unstructured) way. Sensor nodes in terrestrial WSNs must be able to convey data effectively back to the base station in a congested environment [14]. Since the battery is depleted, they have solar cells as an alternate power source. Multi-hop optimum routing, short-distance transmission range, in-network data aggregation, and low-duty cycle operation can all help save energy [15]. Environmental sensing and monitoring, industrial monitoring, agricultural monitoring, and surface explorations are all common uses for terrestrial WSNs.

B. Underground WSN

These type of WSN are used to monitor underground conditions in mines, caves [16] etc. Because they require special equipment to enable consistent transmission through rocks, soil and water, they are more costly than terrestrial WSNs. The underground WSNs that have been installed in the ground are hard to recharge. Underground WSNs are utilized in a variety of applications, including agriculture monitoring, landscape management, soil, water, and mineral monitoring, and military border surveillance.

C. Underwater WSN

Unlike underground WSNs, this form of WSN is placed underwater. Some of the challenges faced includes; restricted bandwidth, long propagation delays, excessive latency, signal fading and sensor failures, as well as battery energy limitations. Aquatic life study and monitoring, mineral and oil deposit monitoring, undersea surveillance, water pollution monitoring, disaster management monitoring, and seismic monitoring are all applications of underwater WSNs.

D. Multimedia WSN

This sort of WSN allows for the tracking and monitoring of multimedia events such as videos, photos, and sounds. The sensor nodes in the network are low-cost and integrated with cameras and microphones. For data compression, these nodes are connected to each other through a wireless connection. High energy consumption, high bandwidth requirements, data processing, and compression techniques are all issues with multimedia WSNs. In addition, they have a wide range of applications which includes; home monitoring, structural health monitoring, etc.

E. Mobile WSN

This type of WSN is made up of mobile sensor nodes that are able to interact with their surroundings [17]. In addition to sensing, computing, and communicating, mobile nodes are capable of reposition and arrange themselves in the network. Also, in contrast to fixed routing in static WSN, a dynamic routing method must be used. Limited bandwidth, mobility management, localization with mobility, navigation, and control of mobile nodes, maintaining proper sensor coverage, limiting energy consumption in locomotion, preserving network connectivity, and data dissemination are just a few of the issues that mobile WSNs encounter. Monitoring of environmental conditions, military surveillance, target tracking, search and rescue are some of the areas of application of mobile WSN. When compared to static sensor nodes, mobile sensor nodes provide more coverage and connection.

IX. Conclusion

To conclude this paper, WSNs are becoming increasingly important in the communication sector, despite the fact that they are still in their early stages of development, there are a number of challenges that still needs to be resolved. Inspite of the challenges and shortcomings, they provide services that are essential in everyday applications. Security, energy efficiency, scalability, compatibility, and other key aspects will always pose some be challenges, but they could be resolved through extensive research and advancement in technology.

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