**CHAPTER ONE**

**INTRODUCTION**

**1.0 BACKGROUND TO THE STUDY**

The first wireless trend known as Wireless voice networks emerged in the 1980s. By 1999, wireless data networks had begun. Today, we are entering the third wireless revolution. It is also known as the Internet of Things, the third wave is utilizing wireless sense and control technology to bridge the gap between the physical world of humans and the virtual world of electronics. The dream is to automatically monitor and respond to forest fires, avalanches, hurricanes, faults in country wide utility equipment, traffic, hospitals and much more over wide areas and with billions of sensors. It will become possible due to the development of Wireless Sensor Networks (WSN) otherwise known as Ubiquitous Sensor Networks (USN).

Wireless sensor networks (WSNs) have gained worldwide attention in recent years, particularly with the proliferation in Micro-Electro-Mechanical Systems (MEMS) technology which has facilitated the development of smart sensors. These sensors are small, with limited processing and computing resources, and they are inexpensive compared to traditional sensors. These sensor nodes can sense, measure, and gather information from the environment and, based on some local decision process, they can transmit the sensed data to the user.

Since the start of the third Millennium, wireless sensor networks (WSNs) generated an increasing interest from industrial and research perspectives. Scholars such as Akyildiz, et al (2002), Tubaishat & Madria (2003), Hac (2003), and Raghavendra, et al. (2004) have been interested on the industrial perspective of WSNs while Sohrabi, et al. (2000) Culler, et al (2004) and Rajaravivarma, et al. (2003) have, on the other hand, have been concerned with the research perspective of WSNs. A WSN can be generally described as a network of nodes that cooperatively sense and may control the environment enabling interaction between persons or computers and the surrounding environment (Verdone, et al, 2008). On one hand, WSNs enable new applications and thus new possible markets, on the other hand, the design is affected by several constraints that call for new paradigms. In fact, the activity of sensing, processing, and communication under limited amount of energy, ignites a cross-layer design approach typically requiring the joint consideration of distributed signal/data processing, medium access control, and communication protocols (Verdone, 2008).

WSNs have several common aspects with wireless ad hoc network (Basagni, et al, 2004) and in many cases they are simply considered as a special case of them. This could be lead to erroneous conclusions, especially when protocols and algorithms designed for ad hoc networks are used in WSN.

A WSN can be defined as a network of devices, denoted as *nodes*, which can sense the environment and communicate the information gathered from the monitored field (e.g., an area or volume) through wireless links (Akyildiz, et al, 2002; Tubaishat & Madria, 2003; Hac, 2003; Raghavendra, et al, 2004; Sohrabi, et al, 2000; Culler, 2004, et al; Rajaravivarma, et al, 2003; Verdone, et al, 2008; Verdone, 2008; Basagni, et al, 2004). The data is forwarded, possibly via multiple hops, to a *sink* (sometimes denoted as *controller* or *monitor*) that can use it locally or is connected to other networks (e.g., the Internet) through a *gateway*. The nodes can be stationary or moving. They can be aware of their location or not. They can be homogeneous or not. Almost all scientific papers in the literature deal with such a definition. This single-sink scenario suffers from the lack of scalability: by increasing the number of nodes, the amount of data gathered by the sink increases and once its capacity is reached, the network size cannot be augmented. Moreover, for reasons related to MAC and routing aspects, network performance cannot be considered independent from the network size.

A more general scenario includes multiple sinks in the network. Given a level of node density, a larger number of sinks will decrease the probability of isolated clusters of nodes that cannot deliver their data owing to unfortunate signal propagation conditions. In principle, a multiple-sink WSN can be scalable (i.e., the same performance can be achieved even by increasing the number of nodes), while this is clearly not true for a single-sink network. However, a multi-sink WSN does not represent a trivial extension of a single-sink case for the network engineer. In many cases nodes send the data collected to one of the sinks, selected among many, which forward the data to the gateway, toward the final user. From the protocol viewpoint, this means that a selection can be done, based on a suitable criterium that could be, for example, minimum delay, maximum throughput, minimum number of hops, etc. Therefore, the presence of multiple sinks ensures better network performance with respect to the single-sink case (assuming the same number of nodes is deployed over the same area), but the communication protocols must be more complex and should be designed according to suitable criteria.

The main features of WSNs, as could be deduced by the general description given, are: scalability with respect to the number of nodes in the network, self-organization, self-healing, energy efficiency, a sufficient degree of connectivity among nodes, low-complexity, low cost and size of nodes. Those protocol architectures and technical solutions providing such features can be considered as a potential framework for the creation of these networks, but, unfortunately, the definition of such a protocol architecture and technical solution is not simple, and the research still needs to work on it (Sohrabi, et al, 2000).

These wireless sensor networks and the challenges accompanying their usage and applications within the Jalingo metropolis shall be the crux of this study.

**1.1 STATEMENT OF THE PROBLEM**

As new technologies continue to emerge and gain popularity, they pose some challenges in application and usage to third world countries. These challenges are usually, somewhat, unique to regions and times and if not researched, may not be taken into consideration during upgrades and improvements by manufacturers.

There appears to be a yawning gap in research of the challenges of WSNs as peculiar to Jalingo in particular, Taraba state at large and Nigeria on a larger scale. Since there has been little or no research, the general challenges are usually applied to the study area resulting to unattended potential challenges which lead to system breakdown and/or malfunction. The researchers therefore, are poised at providing this information by way of statistical study which may be a starting point for improvements in WSNs.

**1.2 AIM AND OBJECTIVES OF THE STUDY**

The aim of this study is to examine the challenges of wireless sensor networks in Jalingo. Based on this aim, the following objectives have been formulated by the researchers to help them succeed in the study:

1. to examine access and exposure to WSNs in Jalingo;
2. to find out the nature of challenges associated with WSNs in Jalingo; and
3. to find out the implication of these challenges to the users and the people of Jalingo.

**1.3 SIGNIFICANCE OF THE STUDY**

This study will contribute timely to the scarce academic literature available on the subject of WSNs. It shall serve as research material for further studies by students and lecturers alike. This study shall also be a useful tool to policy formulators and implementers in the field of Wireless technology in Nigeria.

**1.4 SCOPE AND LIMITATION**

The geographical scope of this study is the Jalingo metropolis excluding outskirts such as Kona, etc. This is so done considering financial and time constraints faced by the researchers. The study is focused only on wireless sensor networks excluding every other form of wireless networks which may be available in Jalingo.

Major limitations to this study include money and time. Also, lack of comprehensive records on the number of WSNs used in the metropolis is a limitation hence, the researchers will have to scout likely points to gather the study population to the best of their efforts and also considering time and resources. Another limitation of this study is the meager quantity of information possessed by residents of the Jalingo metropolis on WSNs as a technical term, which makes the data collection process participatory.

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**CHAPTER TWO**

**LITERATURE REVIEW**

**2.0 INTRODUCTION**

Today sensors are everywhere. We take it for granted, but there are sensors in our vehicles, in our smart phones, in factories controlling CO2 emissions, and even in the ground monitoring soil conditions in vineyards. While it seems that sensors have been around for a while, research on wireless sensor networks (WSNs) started back in the 1980s, and it is only since 2001 that WSNs generated an increased interest from industrial and research perspectives. This is due to the availability of inexpensive, low powered miniature components like processors, radios and sensors that were often integrated on a single chip (system on a chip (SoC)).

The massive research on WSNs started after the year 2000. However, it took advantage of the outcome of the research on wireless networks performed since the second half of the previous century. In particular, the study of ad hoc networks attracted a lot of attention for several decades, and some researchers tried to report their skills acquired in the field of ad hoc networks, to the study of WSNs. These researches and discourses shall be perused and reviewed in this chapter.

**2.1 REVIEW OF RELATED LITERATURE**

A wireless sensor network is a collection of nodes organized into a cooperative network (Hill, et al, 2000). Each node consists of processing capability (one or more microcontrollers, CPUs or DSP chips), may contain multiple types of memory (program, data and flash memories), have a RF transceiver (usually with a single omni-directional antenna), have a power source (e.g., batteries and solar cells), and accommodate various sensors and actuators. The nodes communicate wirelessly and often self-organize after being deployed in an ad hoc fashion. Wireless sensor networks (WSNs) are an important technology for large-scale monitoring, providing sensor measurements at high temporal and spatial resolution.

Recent technological improvements have made the deployment of small, inexpensive, low-power, distributed devices, which are capable of local processing and wireless communication, a reality. Such nodes are called as sensor nodes. Each sensor node is capable of only a limited amount of processing. But when coordinated with the information from a large number of other nodes, they have the ability to measure a given physical environment in great detail. Thus, a sensor network can be described as a collection of sensor nodes which co-ordinate to perform some specific action. Unlike traditional networks, sensor networks depend on dense deployment and co-ordination to carry out their tasks.

Previously, sensor networks consisted of small number of sensor nodes that were wired to a central processing station. However, nowadays, the focus is more on wireless, distributed, sensing nodes. But, why distributed, wireless sensing (Estrin, Girod, Pottie and Srivastava, 2011)? When the exact location of a particular phenomenon is unknown, distributed sensing allows for closer placement to the phenomenon than a single sensor would permit. Also, in many cases, multiple sensor nodes are required to overcome environmental obstacles like obstructions, line of sight constraints etc. In most cases, the environment to be monitored does not have an existing infrastructure for either energy or communication. It becomes imperative for sensor nodes to survive on small, finite sources of energy and communicate through a wireless communication channel.

Another requirement for sensor networks would be distributed processing capability. This is necessary since communication is a major consumer of energy. A centralized system would mean that some of the sensors would need to communicate over long distances that leads to even more energy depletion. Hence, it would be a good idea to process locally as much information as possible in order to minimize the total number of bits transmitted.

**Example of Wireless Sensor Network Design**

Owing to the plethora of features, WSNs design involves a wide range of aspects and considerations and often imposes that several issues, like connectivity, access to the channel, signal processing techniques, etc., must be accounted for together.

As an example, in (Dardari, et al, 2007) a self-organizing single-sink WSN, enabling environmental monitoring through the estimate of a scalar field over a bi-dimensional scenario, is considered. Nodes are assumed to be distributed according to a Poisson point process (PPP) over the area and are organized in a cluster-based topology. Connectivity issues, randomness of the channel, MAC issues and the role of distributed digital signal processing (DDSP) techniques are jointly accounted for, in a mathematical framework developed in the paper. Owing to the requirement of low device complexity together with low energy consumption (i.e., long network lifetime), a proper balance between communication and signal processing capabilities must be found. The adoption of DDSP techniques aims at reducing the amount of transmitted data over the wireless medium; on the other hand, the complexity of the signal processing performed at a single node has to be kept under control (Zhao, et al, 2003; Chiasserini & Rao, 2002; Severi, et al, 2007; Dick, et al, 2001). In (Dardari, et al, 2007) the possibility that nodes perform DDSP is studied through a distributed compression technique based on signal re-sampling. The DDSP impact on network energy efficiency is compared through a novel mathematical approach to the case where the processing is performed entirely by the sink.

The model developed allows the analysis of the network under two different perspectives: the estimation of the process and the energy consumption. The trade-off between energy conservation and estimation error is discussed and a design criterion proposed. As an example result, the required node density is found as a trade-off between estimation quality and network lifetime for different system parameters and scalar field characteristics. It is shown that both the DDSP technique and the MAC protocol choice has a relevant impact on the performance of a WSN.

The main goal of (Dardari, et al, 2007) is neither to design specific communication protocols, nor DDSP techniques; rather, the joint consideration of all aspects mentioned, under realistic but simple working conditions, aims at stressing their interdependencies in a formalized framework.

Therefore, being the goal of (Dardari, et al, 2007), the proposal of a new approach for designing WSNs suffers the following limits: (i) a single-sink scenario and not the more general multi-sink scenario, is accounted for; (ii) the MAC protocol is very simple (slotted ALOHA), and no reference to any specific standard air interface is provided.

In Verdone, et al (2008), Buratti, et al (2009) and Fabbri, et al (2009), a multi-sink WSN, collecting data from the environment through the sampling of some physical entities and sending them to some external user, through multiple sinks, is considered. Through a simple polling model, sinks periodically issue queries, causing all sensors perform sensing and communicating their measurement results back to the sinks they are associated with.

**Sensor Networking Systems**

This section looks at some systems based on sensor-networking concepts, which have been developed by various groups. Most of the systems deal with location of persons/objects.

The **Active Badge Location System** (Want, et al, 1992 and Ward, et al, 1997) is a system for locating personnel/objects inside a building. Each person/object, which has to be located, is tagged with an Active Badge which emits a unique infrared code every 10th of a second. These signals are picked up by networked sensors around the building. On the basis of the information provided by the sensor the location of the tag and hence the person/object can be determined. This system is actually in commercial use now.

**Pin-point 3D-iD local positioning system** described in (Web and Lanz, 1998) also deals with a similar problem of locating an item in 3-D space inside a location fixed by boundaries. The system consists of 3D-iD readers and tags. The readers emit codes that are received by the tags and transponded back to the reader after changing the signal's frequency. Based on the round trip time of flight, the distance of the tag from the antenna is calculated. It has an accuracy of 1-3metres. Ward, et al (1997) present a sensor system which also allows the location of indoor people or equipment to be calculated but more accurately i.e. within 15cm of their actual location. A small wireless transmitter is attached to every object to be located. A matrix of receiver elements equipped with ultrasonic detectors are mounted on the room of the ceiling. The position of the transmitter is calculated using multilateration techniques.

**Scalable Object-tracking through Unattended Techniques (SCOUT)** (Kumar, et al, 2000) is a hierarchical, self-configuring approach for object location. It describes two schemes. SCOUT-AGG is a technique based on aggregation and naming. The objects are organized into a hierarchy. Each object has an object name based on the hierarchy. For example, conf\_equipment.projector.146 defines a unique projector with id 146. On receiving a query, a sensor checks if the object is monitored locally, else it attaches its id to the query and forwards the query to its parent. The process is repeated till the sensor with the requested information is reached.

SCOUT-MAP again organizes the sensors into a hierarchy. Also each sensor has a radius which determines the number of hops that an advertisement from that node will be allowed to propagate. Mapping of objects to locator sensor addresses is carried based on an algorithm. Priyantha et al. (2000) discuss the Cricket Location-Support System which helps devices learn where they are and lets them decide whom to advertise this information to. It does not rely on centralized management and there is no explicit co-ordination among the beacons. Here beacons are attached to some unobstrusive location. The objects which need to be located have listeners attached to them. When an object is deployed into the network, the listener infers its current location from the set of beacons it hears. The Cricket system uses a combination of RF and ultrasound hardware. Though the system has the advantage that it is decentralized and hence easy to manage and configure, it has the drawback that there is no explicit co-ordination. Hence RF signals from various beacons might collide. Thus it is the responsibility of the listener to analyze the various RF and ultrasound samples and deduce the correct RF,US pairs.

**WSNs for Applications**

The applications for WSNs are varied, typically involvingsome kind of monitoring, tracking, or controlling. Specificapplications include habitat monitoring, object tracking,nuclear reactor control, fire detection, and traffic monitoring.In a typical application, a WSN is scattered in a region whereit is meant to collect data through its sensor nodes.

1. **Area monitoring:** Area monitoring is a common application of WSNs. In area monitoring, the WSN is deployed over a region where some phenomenon is to be monitored. For example, a large quantity of sensor nodes could be deployed over a battlefield to detect enemy intrusion instead of using landmines. When the sensors detect the event being monitored (heat, pressure, sound, light, electromagnetic field, vibration, etc), the event needs to be reported to one of the base stations, which can take appropriate action (e.g., send a message on the internet or to a satellite). Depending on the exact application, different objective functions will require different data-propagation strategies, depending on things such as need for real-time response, redundancy of the data (which can be tackled via data aggregation and information fusion techniques), need for security, etc.
2. **Environmental monitoring:** A number of WSNs have been deployed for environmental monitoring. Many of these have been short lived, often due to the prototype nature of the projects. Examples of longer-lived deployments are monitoring the state of permafrost in the Swiss Alps: The PermaSense Project, PermaSense Online Data Viewer and glacier monitoring.
3. **Water/Wastewater Monitoring:** There are many opportunities for using wireless sensor networks within the water/wastewater industries. Facilities not wired for power or data transmission can be monitored using industrial wireless I/O devices and sensors powered using solar panels or battery packs. As part of the American Recovery and Reinvestment Act (ARRA), funding is available for some water and wastewater projects in most states.
4. **Landfill Ground Well Level Monitoring and Pump Counter:** Wireless sensor networks can be used to measure and monitor the water levels within all ground wells in the landfill site and monitor leach ate accumulation and removal. A wireless device and submersible pressure transmitter monitors the leach ate level. The sensor information is wirelessly transmitted to a central data logging system to store the level data, perform calculations, or notify personnel when a service vehicle is needed at a specific well.

It is typical for leachate removal pumps to be installed with a totalizing counter mounted at the top of the well to monitor the pump cycles and to calculate the total volume of leach ate removed from the well. For most current installations, this counter is read manually. Instead of manually collecting the pump count data, wireless devices can send data from the pumps back to a central control location to save time and eliminate errors. The control system uses this count information to determine when the pump is in operation, to calculate leachate extraction volume, and to schedule maintenance on the pump.

1. **Flare Stack Monitoring:** Landfill managers need to accurately monitor methane gas production, removal, venting, and burning. Knowledge of both methane flow and temperature at the flare stack can define when methane is released into the environment instead of combusted. To accurately determine methane production levels and flow, a pressure transducer can detect both pressure and vacuum present within the methane production system.

Thermocouples connected to wireless I/O devices create the wireless sensor network that detects the heat of an active flame, verifying that methane is burning. Logically, if the meter is indicating a methane flow and the temperature at the flare stack is high, then the methane is burning correctly. If the meter indicates methane flow and the temperature is low, methane is releasing into the environment.

1. **Water Tower Level Monitoring:** Water towers are used to add water and create water pressure to small communities or neighborhoods, during peak, use times to ensure water pressure is available to all users. Maintaining the water levels in these towers is important and requires constant monitoring and control. A wireless sensor network that includes submersible pressure sensors and float switches monitors the water levels in the tower and wirelessly transmits this data back to a control location. When tower water levels fall, pumps to move more water from the reservoir to the tower are turned on.
2. **Agriculture:** The use wireless sensor networks within the agricultural industry is increasingly common. Gravity fed water systems can be monitored using pressure transmitters information technology research needs to monitor water tank levels, pumps can be controlled using wireless I/O devices, and water use can be measured and wirelessly transmitted back to a central control center for billing. Irrigation automation enables more efficient water use and reduces waste.
3. **Windrow Composting:** Composting is the aerobic decomposition of biodegradable organic matter to produce compost, a nutrient-rich mulch of organic soil produced using food, wood, manure, and/or other organic material. One of the primary methods of composting involves using windrows.

To ensure efficient and effective composting, the temperatures of the windrows must be measured and logged constantly. With accurate temperature measurements, facility managers can determine the optimum time to turn the windrows for quicker compost production. Manually collecting data is time consuming, cannot be done continually, and may expose the person collecting the data to harmful pathogens. Automatically collecting the data and wirelessly transmitting the data back to a centralized location allows composting temperatures to be continually recorded and logged, improving efficiency, reducing the time needed to complete a composting cycle, and minimizing human exposure and potential risk.

An industrial wireless I/O device mounted on a stake with two thermocouples, each at different depths, can automatically monitor the temperature at two depths within a compost windrow or stack. Temperature sensor readings are wirelessly transmitted back to the gateway or host system for data collection, analysis, and logging. Because the temperatures are measured and recorded continuously, the composting rows can be turned as soon as the temperature reaches the ideal point. Continuously monitoring the temperature may also provide an early warning to potential fire hazards by notifying personnel when temperatures exceed recommended ranges.

1. **Greenhouse Monitoring:** Wireless sensor networks are also used to control the temperature and humidity levels inside commercial greenhouses. When the temperature and humidity drops below specific levels, the greenhouse manager must be notified via e-mail or cell phone text message, or host systems can trigger misting systems, open vents, turn on fans, or control a wide variety of system responses. Because some wireless sensor networks are easy to install, they are also easy to move as the needs of the application change (Bulusu, et al, 2002).
2. **Vehicle Detection:** Wireless sensor networks can use a range of sensors to detect the presence of vehicles ranging from motorcycles to train cars.

**Challenges of Wireless Sensor Networks**

In spite of the diverse applications, sensor networks pose a number of unique technical challenges due to the following factors:

1. **Power:** This is usually the greatest challenge accompanying WSNs. Most of them have small batteries as power sources which may not be durable enough to sustain the entire monitoring. Hence, the process is interrupted when the battery voltage (with no back up) runs out.
2. **Ad hoc deployment:** Most sensor nodes are deployed in regions which have no infrastructure at all. A typical way of deployment in a forest would be tossing the sensor nodes from an aeroplane. In such a situation, it is up to the nodes to identify its connectivity and distribution.
3. **Unattended operation:** In most cases, once deployed, sensor networks have no human intervention. Hence the nodes themselves are responsible for reconfiguration in case of any changes.
4. **Untethered:** The sensor nodes are not connected to any energy source. There is only a finite source of energy, which must be optimally used for processing and communication. An interesting fact is that communication dominates processing in energy consumption. Thus, in order to make optimal use of energy, communication should be minimized as much as possible.
5. **Dynamic changes:** It is required that a sensor network system be adaptable to changing connectivity (for e.g., due to addition of more nodes, failure of nodes etc.) as well as changing environmental stimuli. Thus, unlike traditional networks, where the focus is on maximizing channel throughput or minimizing node deployment, the major consideration in a sensor network is to extend the system lifetime as well as the system robustness (Estrin, Girod, Pottie and Srivastava, 2011).
6. **Hardware Cost:** The current cost of each individual sensor unit is still very high. Commercially available platforms cost in the order of Rs. 5000 per unit with temperature, humidity and light sensors when bought in large quantities. Capable sensors able to track human mobility inside buildings are costing around Rs.15000 per unit.
7. **System Architecture:** There is no unified system and networking architecture that is stable and mature enough to build different applications on top. Most of the applications and research prototypes are vertically integrated in order to maximize performance.
8. **Wireless Connectivity:** Wireless communication in indoor environments is still quite unpredictable using low-power consumption RF transceivers, in particular in clutter environments common inside buildings, with many interfering electromagnetic fields, such as the one produced by elevators, machinery and computers, among others.
9. **Programmability:** Some form of network re-programmability is desirable; doing so in energy and communication conservative form remains a challenge.
10. **Security:** The security challenges are at many levels.

* From the system point of view, it is critical that the information provided by the nodes be authenticated and the integrity verified, since this information provides the feedback loop to expensive equipment controlling power consumption in the building.
* From the users’ point of view, it is also critical that this information cannot be easily spoofed and remains protected in the back end processor, since it may affect the privacy of users.

Each of the challenges above set the direction for many of the information technology research needs.

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**CHAPTER THREE**

**RESEARCH METHODOLOGY**

**3.0 INTRODUCTION**

All researches are based on underlying philosophical assumptions about what constitutes valid research and which research method(s) is/are appropriate for the development of knowledge in a given study. In order to conduct and evaluate any research, it is important to know what these assumptions are. This chapter discusses the philosophical assumptions and also the design and strategies underpinning this study. In addition, the chapter discusses the research methodologies, and design used in the study including strategies, instruments, and data collection and analysis methods, while explaining the stages and processes involved in the study.

Methodology is the theoretical study of method. It is also seen as a structured set of steps, components and perspectives that people use in their research. Methodology enables the researcher present the procedure he intends to use while conducting the research. Methodology allows that researchers use the opportunity to state and outline how they wish to accomplish a research work (Blurtit, 2008 in Ohaja, 2003).

This research is quantitative in nature. Quantitative research is the controlled, objective, and systematic in gathering of data, which can be generalized to larger populations (Stacks, 2002 in Lagares and Puerto, 2010).

In quantitative research works, a single reality can be measured by an instrument and relationships between measured variables are established. Also, procedures can be established and hypotheses formulated before research can begin. Quantitative research works are also characterized by the deduction making; and the researcher is ideally an objective observer who neither participates in nor influences what is being studied.

Quantitative research methods allow researchers to draw statistical inferences about a population. Researchers may conclude, within a certain confidence level (how certain they are that the results are correct), that the findings hold true not only for those surveyed, but also for the entire population within that sample frame (Broom & Dozier, 1990 in Ohaja, 2002).

This research is aimed at describing the challenges of wireless sensor networks in Jalingo, Taraba state. In other words, it is descriptive in nature.

One common quantitative research method is the survey. It involves drawing up a set of questions on various subjects or on various aspects of a subject to which selected members of a population are requested to react (Sobowale, 2008).

The survey sample frame defines the particular population under study (for example, all the people that use wireless sensor networks in Jalingo). The size of the sample depends on budget, and the margin of error and degree of uncertainty with which the researcher can tolerate. A larger sample increases both accuracy and costs (Williams, 2003). Survey questions must be carefully constructed. Unlike qualitative studies, quantitative research puts limits on respondents’ choices. In a qualitative study, a researcher might ask a broad question such as, “What are some of the things you like about the Morris School District”? A quantitative survey usually provides response choices or options from which responses may be chosen.

**3.1 RESEARCH DESIGN**

A research design articulates what data is required, what methods are going to be used to collect and analyse data, and how all of these will answer one’s research questions. Both data and methods, and the way in which these will be configured in the research project, need to be the most effective in producing the answers to the research question (taking into account practical and other constraints of the study).

A research design is the blue print that addresses the problems of any scientific study. Ohaja (2003) notes that the research topic gives clue to the researcher’s plan that should be adopted. Hence, as a methodology, the researcher adopts the descriptive survey method (Scandura and Williams, 2000 in Lagares and Puerto, 2010).

According to Joseph (2003) in Adeyemi and Jimoh (2010), the survey technique involves drawing up questions on various aspects of a subject to which selected members of a particular population are requested to react. Joseph presents four (4) key points about survey viz:

1. Survey is based on interviewing people and asking them for information;
2. Survey is done to collect and analyse social, economic, psychological, technical and other types of data;
3. Survey is done with a representative sample of the population being studied; and
4. It is assumed that the information obtained from the sample is valid for the general population.

The category of survey under challenges of WSNs in this study comprise of the following (though not constants):

* Ad hoc Deployment
* Unattended operation
* Dynamic changes
* Hardware cost
* Wireless connectivity
* Physical

Hence, all questions that shall be asked concerning challenges of WSNs will be centred around the above category to ensure measurability of responses.

**3.2 METHOD OF DATA COLLECTION**

Being a descriptive study, the survey method of data collection will be used. Survey method, according to Nwagbara (2006) in Adefila (2008), is a method of research, which involves collecting, and analyzing data via highly structured and often very detailed interview or questionnaire in order to obtain information from large numbers of respondents presumed to be representative of a specific population. The structured participatory method of data collection will also be used in the study.

**3.3 RESEARCH POPULATION**

Smith (1988), cited in Lagares and Puerto (2010), noted that a population is the entire number of the target audience as defined by the aims and objectives of the study.

The population of this study covers all persons and/or institutions that make use of any form of WSNs in Jalingo, Taraba state, which may comprise hospitals and clinics using oxymeters, construction organisations concerned with testing soil structure, agricultural agencies, etc., during the period which the data was collected. However, such a record has not yet been prepared hence, the exact number of the study population will be unknown. The choice of this category of respondents is because; people who have never used any WSN may not have sufficient knowledge to answer the questions.

**3.4 SAMPLE AND SAMPLING TECHNIQUE**

Sampling is a technique which involves taking a representative portion of the population and using the data collected as research information, which result can be generalized on the entire population at the end of the study. In other words, the sample represents the entire population of study (Sobowale, 2008). A sample is a subgroup of a population. It can also be described as a representative taste of a group. Sampling is related with the selection of a subset of individuals from within a population to estimate the characteristics of whole population.

The two main advantages of sampling are the faster data collection and lower cost (Kish, 1965; Robert, 2004). Each observation measures one or more properties of observable subjects distinguished as independent individuals. In business research, medical research, agriculture research, sampling is widely used for gathering information about a population. Samples are representative in the sense that each sampled unit will represent the characteristics of a known number of units in the population.

Two standard categories of the sampling method exist. These two categories are called probability sampling and non-probability sampling (Ohaja, 2003).

The sampling technique used by the researchers in this study is the non-probability sampling technique where the researchers employ the use of human judgment in the selection of the research sample (Adefila, 2008). The advantage of non-probability sampling is that it is a convenient way for researchers to assemble a sample with little or no cost.

Non-probability sampling is a good method to use when conducting a pilot study, when attempting to question groups who may have sensitivities to the questions being asked and may not want answer those questions honestly, and for those situations when ethical concerns may keep the researcher from speaking to every member of a specific group (Adefila, 2008). Of the many kinds of non-probability sampling techniques available, the purposive technique is adopted as the most suitable for this study.

In purposive sampling, each sample element is selected for a purpose, usually because of the unique position of the sample elements. Purposive sampling may involve studying the entire population of some limited group (directors of shelters for homeless adults) or a subset of a population (mid-level managers with a reputation for efficiency). Or a purposive sample may be a “key informant survey,” which targets individuals who are particularly knowledgeable about the issues under investigation (lms.hse.ru; UNCF, 2000; Rubin and Rubin, 1995).

The purposive or judgmental sampling method is one of the kinds of non-probability sampling techniques, which the researcher uses his or her judgment to choose respondents and select those that best meet the purpose of the study. It is a sampling method in which the researcher picks those considered to possess the required attributes or information required for the study (memoireonline.com; Babbie, 1999 in Adefila, 2008).

The units are selected from the population to answer necessary questions about a certain matter or product. The researcher is then able to select participants based on internal knowledge of the population and individual units. This method is useful if a researcher wants to study a small subset of a larger population in which many members of the subset are easily identified but the enumeration of all is nearly impossible (English, 2005).

The researchers will go to institutions where WSNs are found and conduct the research. Note that the researchers arch-intent is not to study WSNs in themselves and do not suggest that all institutions and persons know about the technology. They are, however, focused on the challenges of the technology, hence, only people who have used the technology will be included in the research.

**3.5 INSTRUMENT OF DATA COLLECTION**

The instrument for data collection in the study is the questionnaire. This is because it is a good instrument to seek the opinions of respondents about certain issue relating to the research problem.

A questionnaire is a special form of correspondence developed to procure authoritative information from a number of persons through the medium of well directed questions (Adefila, 2008). It is a legitimate method of obtaining information in instances where other procedures will not yield good results or will involve too much time, effort or cost. Crasswell (2003) notes that a questionnaire is a data collection instrument whereby respondents are given standardized questions to complete in written form.

In this study, the questionnaire is divided into 4 sections. Section A seeks to examine the demographic characteristics of the respondents and comprises of 4 questions. Section B seeks to examine access and exposure of respondents to WSNs and comprises of 4 questions while Section C aims at examining challenges of WSNs and comprises of 3 questions. Section D is comprised of 3 questions and seeks to examine the implications of the challenges to the jobs of respondents. Hence, the questionnaire is composed of 11 close-ended questions and 3 open-ended questions. Close-ended questions restrict the range of answers available to the respondent. This allows for ease of coding and gain in coding time; it also offers uniformity of responses (Sobowale, 2008). Time is a constraint to this study hence, the use of close-ended questions in the questionnaire.

The questionnaires for this research work will be self-administered (i.e. responded to by the respondents in person) because it is expected that all undergraduate students can read and write. In addition, the involvement of the researcher in filling of a questionnaire may affect the responses of the respondents owing to the fact that the study is a question of perception of moral standards.

**3.6 INSTRUMENT OF DATA PRESENTATION, ANALYSIS AND INTERPRETATION**

Instruments for data presentation, analysis and interpretation include the simple table of frequency and percentages.

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**CHAPTER FOUR**

**DATA PRESENTATION, ANALYSIS AND DISCUSSION**

**4.0 INTRODUCTION**

This chapter contains interpretation and analysis of data collected. Data analysed are presented in simple frequency tables and percentages and illustrated with column bar charts created with the MS Excel package based on the categories of questions responded to in the questionnaire.

For the purpose of this study, 30 copies of questionnaires were distributed and 25 were successfully retrieved and found useful while 5 were not returned or retrieved.

Demographically, 17 respondents (68%) were males while 8 respondents (32%) were females. In terms of occupation, 6 respondents (24%) were health workers, 9 respondents (36%) were agricultural extension workers, 4 respondents (16%) were road construction workers, and 6 respondents (24%) worked in filling stations.

These data (on demography) will be presented in charts on the next page:

**FIGURE 1**

Source: Field Survey, 2016

**FIGURE 2**

Source: Field Survey, 2016

Data collected from the field in this study shall be presented based on the two demographic characteristics of respondents already analysed above and in line with the objectives of the study as well as questions raised elsewhere within the research work.

The following are objectives of this research work:

1. to examine access and exposure to WSNs in Jalingo;
2. to find out the nature of challenges associated with WSNs in Jalingo; and
3. to find out the implication of these challenges to the users and the people of Jalingo.

The following are questions which the findings of this research shall seek to answer:

1. Is there access and exposure to WSNs in Jalingo?
2. What are the challenges associated with WSNs in Jalingo?
3. What are the implication of these challenges to the users and people of Jalingo?

Data analysed are presented in simple frequency tables and percentages and illustrated with column bar charts created with the MS Excel package based on the categories of questions responded to in the questionnaire.

Tables 1 to 5 answer research question one and present data of responses on questions 1 to 3 on the questionnaire based on sex, age, academic level, type of accommodation and membership status of social club(s) of the respondents.

**TABLE 1: ACCESS AND EXPOSURE TO WSNs BASED ON SEX**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **ITEM OF STUDY** | **RESPONSE CATEGORY** | **MALE** | **FEMALE** | **TOTAL** |
| Knowledge of Wireless Sensor Networks | Yes | 17(68%) | 8(32%) | 25(100%) |
| No | 0 (0%) | 0 (0%) | 0 (0%) |
| **TOTAL** |  | **17 (68%)** | **8 (32%)** | **25 (100%)** |
| Usage of Wireless Sensor Networks | Yes | 17(68%) | 8(32%) | 25(100%) |
| No | 0 (0%) | 0 (0%) | 0 (0%) |
| **TOTAL** |  | **17 (68%)** | **8 (32%)** | **25 (100%)** |
| Frequency of usage of Wireless Sensor Networks | Daily | 11(44%) | 7(28%) | 18(72%) |
| Biweekly | 2(8%) | 0(0%) | 2(8%) |
| Weekly | 1(4%) | 1(4%) | 2(8%) |
| Monthly | 0(0%) | 0(0%) | 0(0%) |
| Others | 3(2.9%) | 0(0%) | 3(12%) |
| **TOTAL** |  | **17 (68%)** | **8 (32%)** | **25 (100%)** |
| Application of Wireless Sensor Networks | Health purposes | 15 (60%) | 3 (12%) | 18 (72%) |
| Env. Monitoring | 1 (4%) | 0 (0%) | 1 (4%) |
| Area monitoring | 1 (4%) | 1 (4%) | 2 (8%) |
| Agriculture | 0 (0%) | 3 (12%) | 3 (12%) |
| Vehicle detection | 0 (0%) | 1 (4%) | 1 (4%) |
| Others | 0 (0%) | 0 (0%) | 0 (0%) |
| **TOTAL** |  | **17 (68%)** | **8 (32%)** | **25 (100%)** |

Source: Field Survey, 2016

Table 1 above presents data collected to determine access and exposure to Wireless Sensor Networks based on sex of the respondents. As shown in the table all the respondents affirm to know about and have ever used a Wireless Sensor Network.

The third item studied in the table shows that 18 respondents (72%) use WSNs daily, 11 (44%) are males while 7 (28%) are females. 2 respondents (8%) use WSNs biweekly; all which are males and no females use the sensors biweekly. 2 respondents (8%) use WSNs weekly, 1 (4%) male and 1 (4%) female. No respondent averred to use Wireless Sensor Networks monthly. Also, 3 respondents (12%) (all males) use WSNs sporadically (i.e. not frequently but as circumstances demand).

The fourth item of study in the table is to determine the applications of Wireless Sensor Networks by respondents. As shown in the table 18 respondents (72%), 15 (60%) which are males and 3 (12%) females, use the technology for health purposes. 1 respondents (4%), a male, used WSNs for environmental monitoring. 2 respondents (8%), 1 (4%) male and 1 (4%) female, use WSNs for area monitoring. 3 respondents (12%), all females, use WSNs for agricultural purposes. 1 respondent (4%), a female, used WSNs for vehicle detection.

The numbers 25, 0, 25, 0, 18, 2, 2, 3, 18, 1, 2, 3 and 1 will be constant in presenting data on access and exposure to Wireless Sensor Networks as located at the last column on Table 1.

**TABLE 2: ACCESS AND EXPOSURE TO WSNs BASED ON OCCUPATION**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **ITEM OF STUDY** | **RESPONSE CATEGORY** | **HEALTH WORKERS** | **AGRIC EXTENSION** | **ROAD CONSTRUCTION** | **FILLING STATIONS** | **TOTAL** |
| Knowledge of Wireless Sensor Networks | Yes | 6(24%) | 9(36%) | 4(16%) | 6(24%) | 25 (100%) |
| No | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) |
| **TOTAL** |  | **6(24%)** | **9(36%)** | **4(16%)** | **6(24%)** | **25 (100%)** |
| Usage of Wireless Sensor Networks | Yes | 6(24%) | 9(36%) | 4(16%) | 6(24%) | 25 (100%) |
| No | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) |
| **TOTAL** |  | **6(24%)** | **9(36%)** | **4(16%)** | **6(24%)** | **25 (100%)** |
| Frequency of usage of Wireless Sensor Networks | Daily | 6(24%) | 7(28%) | 1 (4%) | 4(16%) | 18(72%) |
| Weekly | 0 (0%) | 1 (4%) | 1 (4%) | 0 (0%) | 2(8%) |
| Biweekly | 0 (0%) | 0 (0%) | 1 (4%) | 1 (4%) | 2(8%) |
| Monthly | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) | 0(0%) |
| Others | 0 (0%) | 1 (4%) | 1 (4%) | 1 (4%) | 3(12%) |
| **TOTAL** |  | **6(24%)** | **9(36%)** | **4(16%)** | **6(24%)** | **25 (100%)** |
| Application of Wireless Sensor Networks | Health purposes | 6 (24%) | 0 (0%) | 0 (0%) | 0 (0%)s | 6 (24%) |
| Env. Monitoring | 0 (0%) | 0 (0%) | 2 (8%) | 0 (0%) | 2 (8%) |
| Area monitoring | 0 (0%) | 0 (0%) | 2 (8%) | 0 (0%) | 2 (8%) |
| Agriculture | 0 (0%) | 9 (36%) | 0 (0%) | 0 (0%) | 9 (36%) |
| Vehicle detection | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) |
| Others | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) |
| **TOTAL** |  | **6(24%)** | **9(36%)** | **4(16%)** | **6(24%)** | **25 (100%)** |

Source: Field Survey, 2016

As shown in the Table 2 above, all respondents across all sampled occupation agreed to know and use Wireless Sensor Networks. Among the 18 respondents (72%) who used WSNs daily, 6 (24%) were health workers, 7 (28%) were agricultural extension workers, 1 (4%) was a road construction worker while 4 respondents (16%) worked at filling stations. 1 respondent (4%), who was an agric. extension worker used WSNs weekly, the same goes for 1 (4%) road construction worker. 1 (4%) road construction worker and 1 (4%) filling station worker both used WSNs biweekly. 3 respondents (12%) used WSNs sporadically, 1 (4%) was an agric extension worker, same number goes for road construction workers and filling station worker.

**TABLE 3: CHALLENGES OF WSNs BASED ON SEX**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **ITEM OF STUDY** | **RESPONSE CATEGORY** | **MALE** | **FEMALE** | **TOTAL** |
| Satisfaction with services of Wireless Sensor Networks | Yes | 4(16%) | 1(4%) | 5 (20%) |
| No | 13 (52%) | 7(28%) | 20 (80%) |
| **TOTAL** |  | **17 (68%)** | **8 (32%)** | **25 (100%)** |
| Challenges faced while using Wireless Sensor Networks | Yes | 17 (68%) | 8 (32%) | 25 (100%) |
| No | 0 (0%) | 0 (0%) | 0 (0%) |
| **TOTAL** |  | **17 (68%)** | **8 (32%)** | **25 (100%)** |
| Kind of challenges faced using Wireless Sensor Networks | Power/Energy Source | 13(52%) | 4(16%) | 17 (68%) |
| Environmental Changes | 2(8%) | 1(4%) | 3 (12%) |
| Cost | 0 (0%) | 2(8%) | 2 (8%) |
| Wireless Connectivity | 2(8%) | 1(4%) | 3 (12%) |
| Physical | 0 (0%) | 0 (0%) | 0 (0%) |
| Others | 0 (0%) | 0 (0%) | 0 (0%) |
| **TOTAL** |  | **17 (68%)** | **8 (32%)** | **25 (100%)** |

Source: Field Survey, 2016

Table 3 presents data collected to study challenges of WSNs faced by respondents according to sex.

The first item of study is concerned with satisfaction of services of WSNs. 5 respondents (20%) averred to be satisfied with the WSNs, 4 (16%) were males while 1 (4%) was female. 20 respondents (80%) expressed dissatisfaction with services of WSNs, 13 (52%) were males while 7 (28%) were females.

The second item of study is to ascertain whether respondents face any challenge while using Wireless Sensor Networks. As indicated in the table, all the respondents across both sexes face challenges while using Wireless Sensor Networks.

Concerning the third item of study in Table 3, 17 respondents (68%) face power/energy source-related challenges, 13 (52%) were males while 4 (12%) were females. 3 respondents (12%) faced challenges relating to environmental changes, 2 (8%) were males while 1 (4%) was a female. 2 respondents (8%) faced challenges relating with cost, all were females. 3 respondents (12%) faced challenges relating to wireless connectivity, 2 (8%) were males and 1 (4%) were females.

The numbers 5, 20, 25, 0, 17, 3, 2, 3, 0 and 0 will be constant in presenting data on challenges of Wireless Sensor Networks as located at the last column on Table 3.

**TABLE 4: CHALLENGES OF WSNs BASED ON OCCUPATION**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **ITEM OF STUDY** | **RESPONSE CATEGORY** | **HEALTH WORKERS** | **AGRIC EXTENSION** | **ROAD CONSTRUCTION** | **FILLING STATIONS** | **TOTAL** |
| Satisfaction with WSNs | Yes | 0(0%) | 2(8%) | 1(4%) | 2(8%) | 5 (20%) |
| No | 6 (24%) | 7(28%) | 3(12%) | 4 (16%) | 20 (80%) |
| **TOTAL** |  | **6(24%)** | **9(36%)** | **4(16%)** | **6(24%)** | **25 (100%)** |
| Challenges faced while using Wireless Sensor Networks | Yes | 6(24%) | 9(36%) | 4(16%) | 6(24%) | 25 (100%) |
| No | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) |
| **TOTAL** |  | **6(24%)** | **9(36%)** | **4(16%)** | **6(24%)** | **25 (100%)** |
| Kind of challenges faced while using Wireless Sensor Networks | Power/Energy Source | 4(16%) | 6(24%) | 3(12%) | 4(16%) | 17 (68%) |
| Environmental Changes | 1(4%) | 1(4%) | 0 (0%) | 1 (4%) | 3 (12%) |
| Cost | 0 (0%) | 0 (0%) | 1(4%) | 1(4%) | 2 (8%) |
| Wireless Connectivity | 1(4%) | 2(8%) | 0 (0%) | 0 (0%) | 3 (12%) |
| Physical | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) |
| Others | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) |
| **TOTAL** |  | **6(24%)** | **9(36%)** | **4(16%)** | **6(24%)** | **25 (100%)** |

Source: Field Survey, 2016

Table 3 presents data collected to study challenges of WSNs faced by respondents based on occupation.

In the first item of study in the table, 2 (8%) of the 5 (20%) respondents who expressed satisfaction with services of WSNs were agric extension workers, 1 (4%) was a road construction worker and 2 (8%) were people working in filling stations. 6 (25%) of the 20 (80%) respondents who expressed dissatisfaction with services of WSNs were health workers, 7 (28%) were agric extension workers, 3 (12%) were road construction workers while 4 (16%) worked in filling stations.

**TABLE 5: IMPLICATION OF CHALLENGES OF WSNs BASED ON SEX**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **ITEM OF STUDY** | **RESPONSE CATEGORY** | **MALE** | **FEMALE** | **TOTAL** |
| Negative effect of challenges of WSNs on job | Yes | 17 (68%) | 8 (32%) | 25 (100%) |
| No | 0 (0%) | 0 (0%) | 0 (0%) |
| **TOTAL** |  | **17 (68%)** | **8 (32%)** | **25 (100%)** |
| Continuity in the usage of WSNs | Yes | 17 (68%) | 8 (32%) | 25 (100%) |
| No | 0 (0%) | 0 (0%) | 0 (0%) |
| **TOTAL** |  | **17 (68%)** | **8 (32%)** | **25 (100%)** |
| Recommendation for usage of WSNs | Yes | 17 (68%) | 8 (32%) | 25 (100%) |
| No | 0 (0%) | 0 (0%) | 0 (0%) |
| **TOTAL** |  | **17 (68%)** | **8 (32%)** | **25 (100%)** |

Source: Field Survey, 2016

The researchers plead to analyse Tables 5 and 6 together owing to the uniformity of data presented in them.

**TABLE 6: IMPLICATION OF CHALLENGES OF WSNs BASED ON OCCUPATION**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **ITEM OF STUDY** | **RESPONSE CATEGORY** | **HEALTH WORKERS** | **AGRIC EXTENSION** | **ROAD CONSTRUCTION** | **FILLING STATIONS** | **TOTAL** |
| Negative effect of challenges of WSNs | Yes | 6(24%) | 9(36%) | 4(16%) | 6(24%) | 25 (100%) |
| No | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) |
| **TOTAL** |  | **6(24%)** | **9(36%)** | **4(16%)** | **6(24%)** | **25 (100%)** |
| Continuity in usage of WSNs | Yes | 6(24%) | 9(36%) | 4(16%) | 6(24%) | 25 (100%) |
| No | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) |
| **TOTAL** |  | **6(24%)** | **9(36%)** | **4(16%)** | **6(24%)** | **25 (100%)** |
| Recommendation for usage of WSNs | Yes | 6(24%) | 9(36%) | 4(16%) | 6(24%) | 25 (100%) |
| No | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) |
| **TOTAL** |  | **6(24%)** | **9(36%)** | **4(16%)** | **6(24%)** | **25 (100%)** |

Source: Field Survey, 2016

Tables 5 and 6 present data collected to study the implication of the challenges of Wireless Sensor Networks to and/or on the respondents.

As presented in the tables above, all respondents agree that the challenges faced while using WSN have negative effects on their jobs. However, all the respondents affirm that they will continue using the technology in spite of the negative effects birthed by challenges and also recommend that Wireless Sensor Networks be used by others.

This is a pointer that, even though WSNs have challenges, their functionalities outweigh their dysfunctionalities hence the recommendation.

**4.2 DISCUSSION OF FINDINGS**

Based on the identified objectives of this study, the researchers found out that all the respondents that were sampled knew about and have had contact with or used Wireless Sensor Networks in the course of their jobs. This popularity of Wireless Sensor Networks is occasioned by the high dependence on technologies as a substitute for human resources which could incur risks and job hazards.

This finding supports the assertion of scholars such as Shorabi, et al, (2000) who posit that Wireless sensor networks (WSNs) have gained worldwide attention in recent years, particularly with the proliferation in Micro-Electro-Mechanical Systems (MEMS) technology which has facilitated the development of smart sensors. These sensors are small, with limited processing and computing resources, and they are inexpensive compared to traditional sensors. These sensor nodes can sense, measure, and gather information from the environment and, based on some local decision process, they can transmit the sensed data to the user.

We can see (in the data presentation) that WSNs were used mostly for health purposes. This could be because, some anatomical circumstances cannot be observable by humans hence the wide employment of sensors.

In terms of challenges, the study found that most of the respondents are not satisfied with the services of Wireless Sensor Networks owing to challenges ranging from energy source, environmental changes, etc. However, most of the respondents identified energy source or power supply as the major challenge accompanying usage of Wireless sensor Networks.

This finding corroborates the statement made elsewhere in Chapter Two of this study that power or energy source is usually the greatest challenge accompanying WSNs. Most of them have small batteries as power sources which may not be durable enough to sustain the entire monitoring. Hence, the process is interrupted when the battery voltage (with no back up) runs out.

On the implications of the challenges faced while using Wireless Sensor Networks to the jobs, the respondents all aver that they (the sensors) have negative implications on their jobs efficiency and/or effectiveness.

Strikingly, the respondents all agreed to continue using Wireless Sensor Networks and would recommend same for others. Two thoughts are eminent here: first, the goodness or usefulness of the sensors overweighs their ills or, second, that at the present, Wireless Sensor Networks are the only available technologies capable of doing the job. Hence, when the necessary is not available, the available becomes the necessary.

**CHAPTER FIVE**

**SUMMARY, CONCLUSION AND RECOMMENDATION**

**5.0 SUMMARY**

This study is titled *The Challenges of Wireless Sensor Networks in Jalingo.*

Chapter one presents an introduction to the entire study; it contains the background to the study, statement of the problem, objectives of the study, research questions, significance of the study and operational definition of terms.

In chapter two of the study, relevant literatures on the subject of WSNs and their challenges were reviewed.

Chapter three presented the research methodology adopted and the tool used to execute collection of data and how they will be used. It also contained the research population, sampling and the instrument used for data collection.

Chapter four contains tables and charts which were used to present data collected from the field. Also, it contains the discussion of findings which the researcher made in the study.

Chapter five summarizes the whole research work, restates key findings, concludes the study and provides necessary recommendations.

Based on their aim to examine the challenges of WSNs in Jalingo, the researchers found that there is an exposure to WSNs in the metropolis by relevant career fields and that the users attest to the challenges posed by the sensors.

Key findings of the study, as stated elsewhere are as follows:

1. that there is an exposure to Wireless Sensor Networks within the Jalingo Metropolis by those in concerned career fields;
2. that the respondents frequently use these sensors;
3. that all the users always face challenges;
4. that the challenge most faced is that of power source or backup – the energy source does not last long;
5. that in spite of the challenges faced by users, they still prefer WSNs to traditional methods of gathering statistic; and
6. that the users encourage and recommend the use of Wireless Sensor Networks absolutely.

**5.1 CONCLUSION**

This study has found that Wireless Sensor Networks (WSNs) are vital and desirable tools which will soon overtake many technologies of our age. However, there are challenges which users of this relatively young technology face, chief which is power longevity. Respondents complain that the power source does not last long.

**5.2 RECOMMENDATIONS**

Based on the arch-challenge of power identified and other challenges such as cost, wireless connectivity, environmental changes, etc, the researchers make the following recommendations:

1. that manufacturers of Wireless Sensor Networks should improve or upgrade the power source of the sensor by producing batteries that can last longer or solar-charged batteries;
2. that the government work harder to ensure uninterrupted power supply in the country at large and Taraba state in particular;
3. that installations should be made in locations where weather factors such as sun, rainfall and strong wind cannot affect the installations much;
4. that government should subsidize the prices of the sensors so that they can be affordable by individuals and small-scale organizations; and
5. that the government through the auspice of Ministry of Science and Technology sensitise Nigerians and create awareness on the importance and needfulness of Wireless Sensor Networks.

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**APPENDIX**

TarabaState University, Jalingo.

Faculty of science

Department of Mathematical Science

Information Technology.

February, 2016

Dear respondent,

**QUESTIONNAIRE**

We are final year students of the above named department conducting a research on *The Challenges of Wireless Sensor Networks in Jalingo, Taraba state.*

Please, you are kindly requested to complete the questionnaire attached to the best of your knowledge. Be assured that all your responses will be strictly used for academic purposes.

Thank you.

Yours faithfully,

Timothy Ilu TSU/INF/13/0131

**QUESTIONNAIRE**

**INSTRUCTION:** Kindly tick [ √ ] against appropriate options.

**SECTION A: DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS.**

1. **Sex:** Male [ ]; Female [ ]
2. **Occupation:**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
3. **Institution:**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
4. **Department/Unit:**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**SECTION B: ACCESS AND EXPOSURE TO WIRELESS SENSOR NETWORKS**

1. **Do you know what a wireless sensor network is?**
2. Yes [ ]
3. No [ ]
4. **Have you ever used a wireless sensor network?**
5. Yes [ ]
6. No [ ]
7. **How often do you use (a) wireless sensor network(s)?**
8. Daily [ ]
9. Weekly [ ]
10. Biweekly [ ]
11. Monthly [ ]
12. Others (Specify): \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
13. **What do you use wireless sensor network for?**
14. Health purposes [ ]
15. Environmental monitoring [ ]
16. Area monitoring [ ]
17. Agriculture [ ]
18. Vehicle detection [ ]
19. Others (Specify): \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**SECTION C: CHALLENGES OF WIRELESS SENSOR NETWORKS**

1. **Are you always satisfied with the services of wireless sensor networks?**
2. Yes [ ]
3. No [ ]
4. **Do you face any challenge using wireless sensor networks?**
5. Yes [ ]
6. No [ ]
7. **Which challenge do you face using wireless sensor networks?**
8. Power or energy source [ ]
9. Changes in environment [ ]
10. Cost [ ]
11. Wireless connectivity [ ]
12. Physical [ ]
13. Others (Specify): \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**SECTION D: IMPLICATION OF CHALLENGES**

1. **Does this challenge have any negative effect on your work?**
2. Yes [ ]
3. No [ ]
4. **Are you likely to continue using wireless sensor networks?**
5. Yes [ ]
6. No [ ]
7. **Do you encourage an increasing use of wireless sensor networks?**
8. Yes [ ]
9. No [ ]