

Wireless Sensor Networks and Applications

[Ustijana Rechkoska- Shikoska, Eliza Bajrami]

Abstract— Wireless sensor networks (WSNs) had grown in recent years and have a significant potential in different applications including health, environment, military, etc. The successful development and design of WSN is still a challenging task. In current real-world WSN deployments, different programming approaches have been proposed. Several aspects of Wireless sensor networks applications are presented, and an algorithm for forecast of predicting the weather in the next couple of days, using signal processing techniques is presented in this work. An evaluation is made by performing certain simulations; discussion, conclusion and future work goals are given, including the idea of an expansion of this research in WSNs applications in healthcare.

Keywords— Wireless Sensor Networks (WSNs), Applications, Algorithms, Security in WSNs, Design.

I. Introduction

Wireless sensor networks are self-configured and infrastructure-less wireless networks to monitor physical or environmental conditions such as temperature, vibrations, sounds and to cooperatively pass their data through the network to a main location or a sink where the data can be observed and analyzed. A sink or base station acts as an interface between users and the network. One can retrieve information by the network by injecting queries and gathering results from the sink. A wireless sensor network can contain hundreds of thousands of sensor nodes. [1]

There are four basic components in a sensor network: (1) an assembly of distributed or localized sensors; (2) an interconnecting network (usually, but not always, wireless-based); (3) a central point of information clustering; and (4) a set of computing resources at the central point (or beyond) to handle data correlation, event trending, status querying, and data mining. [1]

In the first section of this research a short introduction about wireless sensor networks is given. In the second section we continued with the related work and reviews of papers and books related to WSN, design and applications, and some other interesting aspects.

Continuing with our third section where went through the WSN importance, its applications, the security aspects, the design issues, and the protocols.

However, in the fourth section we have explained the algorithm, methods used, etc.

In the fifth section Testing & Results are presented.

A brief conclusion and future work ideas are given, references used at the end of this work.

II. Related Work

According to Tiwari [2] et al. Wireless Networks (WNs) are any category of computer system that applies wireless statistics networks to plug system nodes. They are computer systems which are usually not connected by cables irrespective of the category. The application of a wireless system aids enterprises to avoid the expensive means of making use of cables for buildings or connecting different equipment settings. The basis of any wireless systems is the radio waves/microwaves, and their application that ensues at the physical advanced level of network construction both for radio waves/microwaves, radio communications systems (RCSs) and other relevant EMWs. These radio waves/microwaves, RCSs and other relevant EMWs as well as mereological variables are useful in the propagation of the refractivity indices in the atmosphere.

Wireless Sensor Networks have a great role to play in Developing Countries. [3] reports on training work on Wireless Sensor Networks. The trainings were 4 days long and targeted 20 participants, composed of researchers, professionals and students from both computer science and other scientific faculties. The training activities were regional ones and used open wireless sensors for the advantages they present.

The lectures were organized with theoretical lectures in the morning and laboratory sessions in the afternoon. Participants from the workshops have deployed wireless sensor networks in their own countries and have come up with some interesting applications.

The use of WSN will also enhance Computer Science curricula in academic institutions of Developing Countries. Long-term data from sensor networks will be valuable for educational purposes and the associated tools for curricula development should be encouraged. The nodes come with the basics of a general purpose platform, but the nature of each application determines the sensing hardware specifics. Sensor design is a fundamental area within WSN. The ability to perform direct measurements of necessary magnitudes, to identify pattern recognition strategies and exploit computational resources appropriately represent engineering challenges that can be addressed in academia.

Ustijana Rechkoska- Shikoska Ph.D
University for Information Science and Technology “ St. Paul the Apostle”
Ohrid, Macedonia

Eliza Bajrami, MSc Candidate
University for Information Science and Technology “ St. Paul the Apostle”
Ohrid, Macedonia

The technology for sensing and control now has the potential for significant advances, not only in science and engineering, but equally important, on a broad range of applications relating to critical infrastructure protection and security, health care, the environment, energy, food safety, production processing, quality of life, and the economy. In addition to reducing costs and increasing efficiencies for industries and businesses, wireless sensor networking is expected to bring consumers a new generation of conveniences, including, but not limited to, remote controlled heating and lighting, medical monitoring, automated grocery checkout, personal health diagnosis, automated automobile checkups, and child care. [4]

[4] is intended to be a high-quality textbook that provides a carefully designed exposition of the important aspects of wireless sensor networks. The text provides thorough coverage of wireless sensor networks, including applications, communication and networking protocols, middleware, security, and management. The book is targeted toward networking professionals, managers, and practitioners who want to understand the benefits of this new technology and plan for its use and deployment. It can also be used to support an introductory course in the field of wireless sensor networks at the advanced undergraduate or graduate levels.

Many vital challenges face the deployment of WSNs such as energy consumption and security issues. [5] Various attacks could be subjects against WSNs and cause damage either in the stability of communication or in the destruction of the sensitive data. Thus, the demands of intrusion detection-based energy-efficient techniques rise dramatically as the network deployment becomes vast and complicated. Qualnet simulation is used to measure the performance of the networks. This paper [4] aims to optimize the energy-based intrusion detection technique using the artificial neural network by using MATLAB Simulink. The results show how the optimized method based on the biological nervous systems improves intrusion detection in WSN. In addition to that, the unsecured nodes are affected the network performance negatively and trouble its behavior. The regress analysis for both methods detects the variations when all nodes are secured and when some are unsecured. Thus, Node detection based on packet delivery ratio and energy consumption could efficiently be implemented in an artificial neural network.

III. Wireless Sensor Networks

Wireless Sensor Networks, WSNs are used everywhere. They consist spatially distributed sensors, and one or more sink nodes (also called base stations). Sensors monitor, in real-time, physical conditions, such as temperature, vibration, or motion, and produce sensory data [6]. A sensor node could behave both as data originator and data router. A sink, on the other hand, collects data from sensors. For example, in an event monitoring application, sensors are required to send data to the sink(s) when they detect the occurrence of events of interest. The sink may communicate with the end-user via

direct connections, the Internet, satellite, or any type of wireless links.

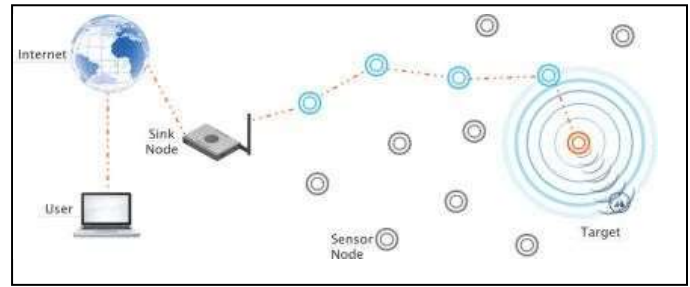


Figure 1. A WSN architecture

There are essentially five categories of WSNs which we thought would be interesting to mention here in relation with further research.

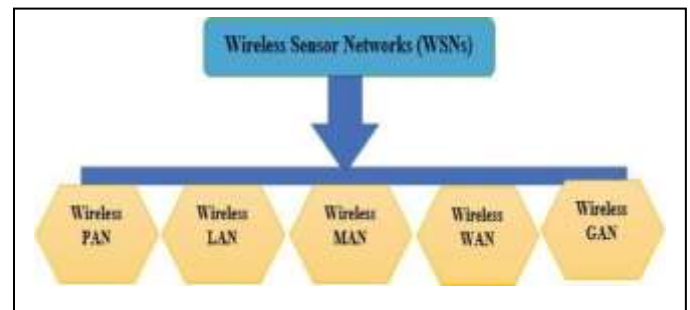


Figure 2. Categories of WSN

- Wireless personal area network (wireless PAN)

This is a WSN that is carried over a low-powered, short-distance WN technology such as Bluetooth network, IrDA, wireless USB or ZigBee. The reach of a wireless PAN differs from a few metres to a few kilometres.

- Wireless local area network (wireless LAN)

This is a WSN or wireless computer network (WCN) that links or connects two or more devices by means of wireless communication (WC) to form a LAN within a restricted location such as a computer research laboratory, household, institution, or workplace. This gives users the capability to move from place to place within the said location and remain connected or linked to the WN. Wireless LAN could also offer a connection to the wider cyberspace (internet) through a gateway. Most contemporary wireless LANs are based on the standards of IEEE 802.11 and are marketed under the Wi-Fi product designation. Wireless LANs have become prevalent for use in the several households, as a result of their ease of installation and use. They are also prevalent in commercial physiognomies that offer wireless access to their workforces and clients.

- Wireless metropolitan area network (wireless MAN)

This is a computer network (CN) that communicates and interconnects users with various computer resources in a geographic location of the size of an urban area. The term MAN is applied to the interconnection of LANs in an urban area into a single greater network which could similarly offer effective connection to a wide area network (WAN)

- Wireless wide area network (wireless WAN)

This is another form of WN. The greater size of a WAN compared to a LAN entails the modifications in technology. WNs of diverse dimensions deliver data in the form of web pages, telephone calls and streaming video. A wireless WAN often differs from wireless LAN by using mobile telecommunication cellular network (MTCN) machineries such as 2G, 3G, 4G LTE, and 5G in transferring data. Wireless WAN is sometime called mobile broadband (MBB). These machineries are existing nationally, regionally, or even globally and are provided by a wireless service provider (WSP). Wireless WAN connectivity permits a user with a CN and a wireless WAN card to surf the network, check electronic mail, or connect to a virtual private network (VPN) from somewhere within the boundaries of WNs.

- Wireless global area network (wireless GAN)

This refers to any network that is composed of diverse interconnected CNs (WANs) and also covers an unrestricted geographical location. It is apprehensively identical with Internet, which is considered as a GAN. Unlike LANs and WANs, GANs cover a much larger geographical area. Since GANs are used for supporting MTCNs across a number of wireless LANs, one of the main challenges for any wireless GAN is in transferring of the user communications from one LAN to another. One of the utmost popular wireless GAN categories is a broadband (BB) wireless GAN. The BB wireless GAN is a worldwide satellite Internet network (SIN) that employs transferrable terminals for telephony. The terminals connect CNs located in LAN to BB Internet.

A. Applications of WSN

Wireless sensor networks have gained considerable popularity due to their flexibility in solving problems in different application domains and have the potential to change our lives in many different ways. We believe our lives have already changed because of the use of multiple WSN applications. WSNs have been successfully applied in various application domains, and their usage is growing every day.

- Forecast and prediction of weather

There are various approaches available in weather [7] forecasting, from relatively simple observation of the sky to highly complex computerized mathematical models. The prediction of weather condition is essential for various applications. Some of them are climate monitoring, drought detection, severe weather prediction, agriculture and production, planning in energy industry, aviation industry, communication, pollution dispersal, and so forth.

- Military applications

Possibly, WSNs is an essential fragment of military intelligence, facility, control, communications, computing, frontline surveillance, investigation and targeting systems. [8]

- Area monitoring

In the aspect, the sensor nodes are positioned over an area where some display is to be observed. When the sensors notice the occurrence being observed (such as temperature, pressure etc), the occurrence is conveyed to one of the base stations (BSs), which then takes action appropriately. [8]

- Transportation

Instantaneous traffic statistics is being composed by WSNs to later forage transportation models and keep the drivers on alert of possible congestion and traffic difficulties.

- Health applications

Some of the medical/health benefits of WSNs are in the areas of diagnostics, investigative, and drug administration as well as management, supporting interfaces for the incapacitated, integrated patient monitoring and management, tele-monitoring of human physiological information, and tracking and monitoring medical practitioners or patients inside the medical facility. According to Nwankwo et al. [9] nanoinformatics and nanomedicine are now beginning to advance in clinical applications via the use of biosensors.

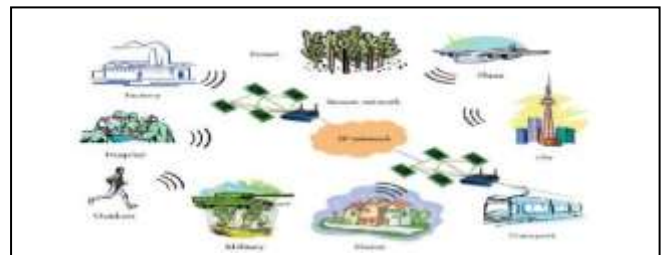


Figure 3. Application areas of WSN

B. Security and privacy issues in WSN

Security is one of the main aspects and challenges of WSNs. They can be easily exposed, and that's why security it's one of the most important challenges which needs to be analyzed. Wireless sensor networks (WSNs) [10] are a type of Ad Hoc networks that consist of a large number of resource-constrained sensor nodes. Requiring no fixed infrastructure, WSNs can be quickly deployed, organized, and maintained in an ad hoc manner. The flexibility in deployment and maintenance advances WSNs' application in many fields, including military, environmental monitoring, public safety monitoring, emergency handling, medical, and oceanic monitoring. For example, WSNs can be used to detect and track the intrusion of enemies or their tanks on a battlefield, to detect forest-fires and floods, to monitor environmental pollutions, or to measure traffic flows in a traffic network. Security is one of the most important issues in WSNs. As WSNs are usually deployed in hostile or remote environments and work in an unattended manner, prevention of network

attack by adversaries and protection of privacy of sensitive collected data is pivotal for many WSNs applications.

Layer	Security Threats
Physical	Jamming Attack, Physical Tampering Attack
Data Link	Collision Attack, Exhaustion Attack, Unfair Competition Attack
Network	False Routing Information Attack, Selective Forwarding Attack, Sink-hole Attack, Sybil Attack, Wormhole Attack, HELLO Flood Attack, Acknowledgment Spoof Attack, Passive Wiretapping Attack
Transport	Flooding Attack, Desynchronization Attack

Figure 4. Main security threats in WSN

- Point to Point Security solution

Among all other security solutions point to point security attracts our interest. Point-to-point security solution involves secure routing between every two nodes along the multi-hop path. To show the design and efficacy of point-to-point solution, there is a fully described point to point security solution for multi-hop based WSNs. Olakanmi and Dada [11] proposed an effective point-to-point security scheme that engages point-to-point (PoP) mutual authentication scheme, perturbation, and pseudonym to overcome security and privacy issues in WSNs. To reduce computational cost and energy consumption, they used elliptic curve cryptography, hash function, and exclusive OR operations to evolve an efficient security solution for a decentralized WSNs. The network model, as shown in Figure 2, consists of base station (BS), immediate node (IN), source node (SN) or (sn), and destination node (DS) or (ds). The SNs and DSs are capable of multi-hop transmission; therefore any SN can become DS and vice versa.

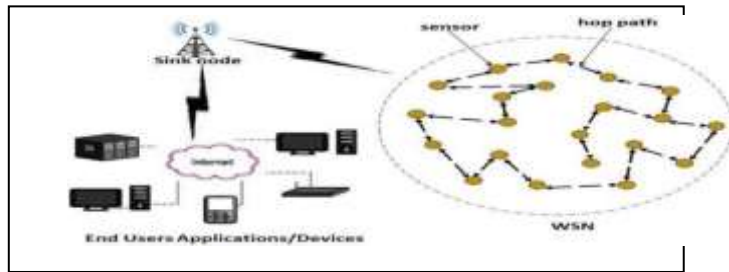


Figure 5. WSN system model

c. Design issues of WSN

There are a lot of challenges placed by the deployment of sensor networks which are a superset of those found in wireless ad hoc networks. Sensor nodes communicate over wireless, with lines with no infrastructure. An additional challenge is related to the limited, usually non-renewable energy supply of the sensor nodes. In order to maximize the lifetime of the network, the protocols need to be designed from the beginning with the objective of efficient management of the energy. They need to be carefully designed and analyzed. According to Matin and Islam [1] some of the specific design challenges in WSNs are:

Fault Tolerance: Sensor nodes are vulnerable and frequently deployed in dangerous environment. Nodes can fail due to hardware problems or physical damage or by exhausting their energy supply. It is expected the node failures to be much higher than the one normally considered in wired or infrastructure-based wireless networks. The protocols deployed in a sensor network should be able to detect these failures as soon as possible and be robust enough to handle a relatively large number of failures while maintaining the overall functionality of the network. This is especially relevant to the routing protocol design, which has to ensure that alternate paths are available for rerouting of the packets. Different deployment environments pose different fault tolerance requirements.

Sensor Network Topology: Although WSNs have evolved in many aspects, they continue to be networks with constrained resources in terms of energy, computing power, memory, and communications capabilities. Of these constraints, energy consumption is of paramount importance, which is demonstrated by the large number of algorithms, techniques, and protocols that have been developed to save energy, and thereby extend the lifetime of the network. Topology Maintenance is one of the most important issues researched to reduce energy consumption in wireless sensor networks.

Power Consumption: As we have already seen, many of the challenges of sensor networks revolve around the limited power resources. The size of the nodes limits the size of the battery. The software and hardware design needs to carefully consider the issues of efficient energy use. For instance, data compression might reduce the amount of energy used for radio transmission, but uses additional energy for computation and/or filtering. The energy policy also depends on the application; in some applications, it might be acceptable to turn off a subset of nodes in order to conserve energy while other applications require all nodes operating simultaneously.

d. Algorithms and protocols of WSN

Some of the most important protocols and algorithms which deal with the WSNs and energy conservation issues:

Flooding is a common technique frequently used for path discovery and information dissemination in wired and wireless ad hoc networks [13]. The routing strategy of flooding is simple and does not rely on costly network topology maintenance and complex route discovery algorithms. Flooding uses a reactive approach whereby each node receiving a data or control packet sends the packet to all its neighbors. After transmission, a packet follows all possible paths. Unless the network is disconnected, the packet will eventually reach its destination. Furthermore, as the network topology changes, the packet transmitted follows the new routes.

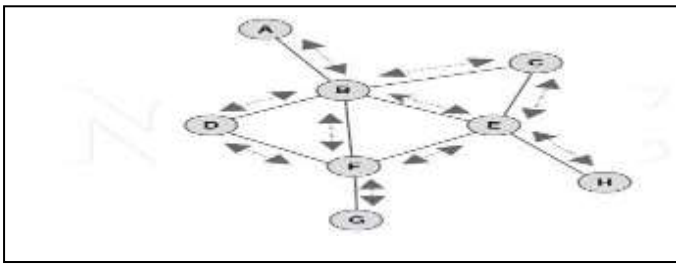


Figure 6. Flooding technique

To address the shortcomings of flooding, a derivative approach, referred to as gossiping [14], has been proposed in. Similar to flooding, gossiping uses a simple forwarding rule and does not require costly topology maintenance or complex route discovery algorithms. Contrary to flooding, where a data packet is broadcast to all neighbors, gossiping requires that each node sends the incoming packet to a randomly selected neighbor. Upon receiving the packet, the neighbor selected randomly chooses one of its own neighbors and forwards the packet to the neighbor chosen. This process continues iteratively until the packet reaches its intended destination or the maximum hop count is exceeded.

A Wireless Sensor Network (WSN) consists of spatially distributed autonomous sensor nodes for monitoring environmental conditions. Energy saving by data reduction in WSN is of great importance. An algorithm which uses Wireless Sensor Networks and prediction methods is of our interest here. Weather forecasting data is used as input.

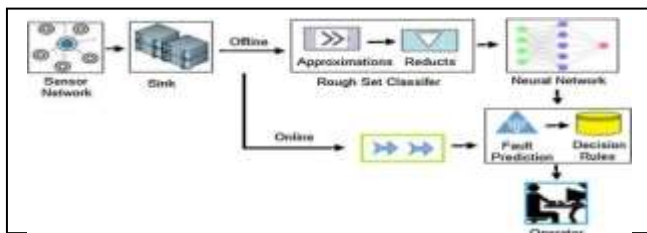


Figure 7. WSNs and Data prediction

Algorithms for data prediction are implemented and different metrics have been used for measuring algorithms performances.

IV. WSN application for weather prediction

Once Wireless Sensor Networks are presented and their applications, as well as this application for weather prediction, simulations are great part of the research. Among all kinds of experiments, the computational experiments or simulations, constitute one of the most active areas at the present time. Modeling and simulation are very generic terms for very different activities, techniques and purposes; it is therefore understandable that simulations have a controversial status amongst theoreticians and practitioners

from different scientific fields. In recent years several studies on philosophy and simulations have appeared, covering a broad spectrum of theoretical aspects related to simulations, such as the relation between models and simulations, simulations in physics or their epistemology. Simulations are about mathematics, models, computer, process and system. Therefore, our best and simplest definition of simulation must be: “a mathematical model that describes or recreates computationally a system process”.

The first step was getting the idea how we will create a simulator which is connected with our research topic of wireless sensor networks.

We live in a world of sensors. they are in our cars, even in our refrigerators and they make sure our food stays fresh. Basically, sensors nowadays are everywhere. So why not create an algorithm using signal processing to predict whether in the next 2 days the weather will be sunny or cloudy? And maybe how it will affect people?

The sensors here generate signals and using simulations to process signal from a sensor, performing a spectral analysis to explore the signal.

There is a scenario with solar panels that generate electrical power, the power depends on the amount of sunshine which depends on the time of day and the weather predicting and managing the variable production and demand is an important part of renewable energy generation to smooth out the generated power on sunny days we can store some of the power in a battery then on cloudy days we use it to supplement the lower power generation.

We simulated an algorithm which predicts if it's going to be sunny or cloudy using signal processing techniques.

We did this work on the Simulink toolbox in MATLAB, Simulink models are built up from blocks and signal lines, so the next step is to open the library browser and see all the blocks available, starting by visualizing two power signals, one from a sunny day and one from the cloudy day. To view our signals, we dragged them to input ports in our model and then added the scope block.

Labeling the two ports, one is the sunny day and one is the cloudy day, and the scope block as time domain. Connecting them both with signal lines and labeled one of them again sunny day and the other one as cloudy day.

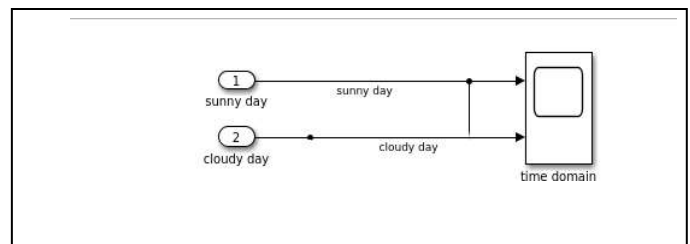


Figure 8. Sunny and Cloudy ports (ALGORITHM)

Imported the data into MatLab named (solararraydata.mat), and the two vectors are sunny and cloudy

day which represent the power measurements for two days. Corresponding time stamps are in 'tday' and also there is the sample frequency in samples per day in the variable FS sampling every 15 minutes means that I get 96 samples per day. Sample time needs to be set on the two imports by double clicking on the import and adjusting its block parameter under the signal attribute. Setting the sample time to the reciprocal of the sampling frequency.

TABLE I. SIMULATON PARAMETERS AND THEIR VALUES

Name	Workspace		
	Value	Size	Class
cloudy Day	96x1 double	96x1	double
Fs	96	1x1	double
out	1x1 simulations	1x1	Simulink
power	91920x 1 double	91920x1	double
Sunny Day	96x1 double	96x1	double
t	91920x1 double	91920x1	double
tday	96x1 double9	6x1	double

This table shows the parameters which are used to implement the correct values for the proposed scenario.

Testing and Results

To bring the data into Simulink the next step was to click onto the model settings on the data import& export and the time and the two power signals as inputs. Also setting the total simulation time to one day. Then running the system by clicking on the run button and double clicking on the scope.

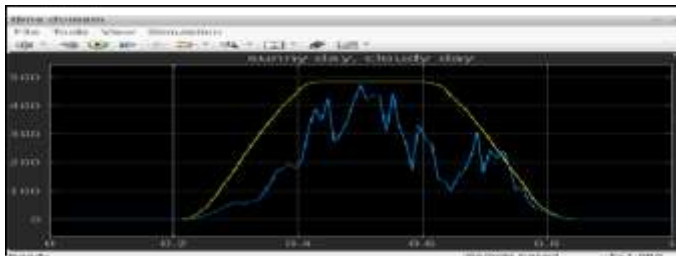


Figure 9. Time Domain Result

Connected the data points using lines. As we can understand the yellow lines are the sunny days and the blue lines show that the cloudy day produces less power and also has many short term variations as the clouds pass over the solar array. The point is how to use this feature to decide if we have a sunny day or a cloudy day. By looking at the signal in the frequency domain using the spectral analysis which helps to measure the frequency content by first adding a spectrum analyzer block naming it frequency domain from the DSP system toolbox and then connecting the two signals to the spectrum analyzer. In the spectrum analyzer block since there were short signals, we needed to change some of the settings to see them properly.

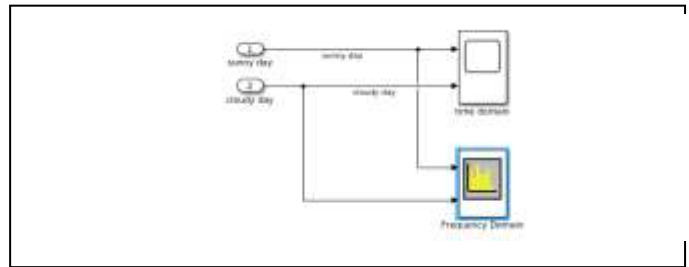


Figure 10. Frequency Domain

The final step was the testing and result part. This is the final step where we can see whether our algorithm is working or not. After changing the settings and everything was working as it should we Ran the model once again.

By clicking on the Legend button to see which days are the Sunny ones and which days are the Cloudy ones. And as provided the yellow lines are the Sunny days, while the blue lines show the cloudy days.

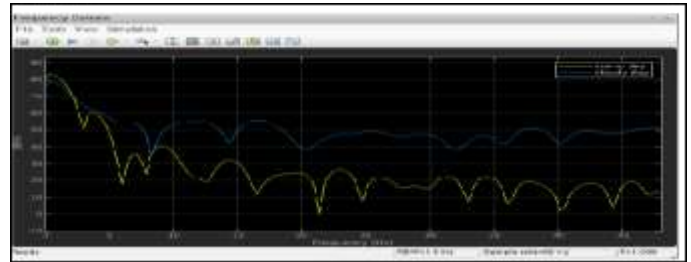


Figure 11. Frequency Domain Final Result

Based on the simulation that we received It can be seen that the x-axis is the frequency value and the y-axis shows how much power is in our signal at a given frequency. Because the default time unit is in seconds, we are actually measuring time in days so the x-axis is cycles per day not cycles per second. The low frequency content is about the same for both days but as it can be seen the cloudy one has way more high frequency content.

The simulation basically predicts if it's going to be sunny or cloudy using signal processing techniques.

v. Conclusion and Future work

Wireless sensor networks, their importance, the various aspects and the algorithms implemented, evaluated are presented in this work. Inspired by great research done for WSNs, a research that discusses multiple aspects and applications of wireless sensor networks is presented. As previously mentioned, wireless sensor networks quickly became part of everyday lives, concerning different fields, resolving environmental, ecology, forecasting, health problems.

As for our future work we plan to explore WSNs in healthcare, we plan to create a system for continual observation of physiological signals of people, affected by environmental issues, while they are at their homes. For

example, they may be affected of these climate changes, sunny or cloudy, or many other things. It will lower the cost involved with monitoring patients and increase the efficient exploitation of physiological data and the patients will have access to the highest quality medical care in their own homes. Thus, it will avoid the distress and disruption caused by a lengthy inpatient stay. The future of WSNs and their medical appliances looks highly promising. We also will proceed with Security issues in WSNs related to solutions previously presented.

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ELIZA BAJRAMI
 Bachelor degree in the study program of E-Business E-Government E-Culture in the faculty of Applied IT, Machine intelligence and Robotics. Currently doing Master studies in the study program of Informatics and Network Security, Privacy and Data Protection.
 With a special interest in Wireless Sensor Networks.



USTIJANA RECHKOSKA-SHIKOSKA
 Ph.D. in Technical Sciences - Computer Sciences and Engineering, "A new space-time localization algorithm for wireless sensor networks" University for Information Science and Technology "St. Paul the Apostle" –Associate Professor in Computer Science and Informatics – present; Vice-Rector for Academic Affairs and International Cooperation 2011-2013; Dean of the Faculty for Computer Science & Engineering CSE 2018-2019; Remarkable activities in Teaching & Research: Computer Engineering, Informatics, Programming, Algorithms & Data Structures, Database Systems, Wireless Sensor Networks, Offensive Security, Electrical Engineering, IT in Power Engineering, Mobile computing, Image Processing, Discrete Mathematics, Digital Signal Processing, Programming; Participating International Conferences, Congresses, International Journals with 101 publications, authoring, co-authoring, International research projects, professional books, Member of Program; Organization Committees of International Conferences, Journals, being Publicity Chair, Editor, Reviewer for years. IEEE member, IARIA member, IRED member; IARIA AICT Certificate 2014, 2015, 2018, 2019; IARIA AICT Panelist Certificate 2018; Certificate for Cyber Security, Norwich University, Vermont, USA, 2012; Golden Certificate for Original Software for an active rectifier, Makinova, 2003; ICT-ACT, ICT Innovations Certificates 2009-2019; Golden Certificate of an Appreciation PCO 2010; Coordinator of an International Practicum for Cyber Security and an International Observatory for Cyber Security with Norwich University, US; An active member of Lions International LD 132, Lions Club Ohrid Desareti, where she works with great enthusiasm on implementing creative ICT solutions.