# INVESTIGATING THE EFFECTS OF VARIOUS PARAMETERS ON EFFICIENCY OF PHYSICAL LAYER DEPLOYED FOR WIRELESS SENSOR NETWORK

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## ABSTRACT

*There is a growing need for research initiatives for Wireless sensor networks with special emphasis on performance and efficiency of physical layer. The role of physical layer is clearly evident from the fact that it plays an important role in determining the overall quality of data communication. The issue of quality is also important in the context of saving energy of nodes involved in wireless sensor network communication. Poor quality of communication puts constraint on the already existing energy sensitive nature of wireless sensor networks. This research work is focused on investigation of critical parameters and their effects on overall communication quality in reference to Physical Layer. One of the key factors is antenna design and other factors include physical layer parameters including delay that can contribute critically in defining the quality. Various antenna designs are incorporated in ns-2 simulation environment along with different physical layer parameters and their impact is assessed and evaluated. This work also demonstrates the compatibility between ns-2, network simulation environment and CST, antenna design simulation environment.*

**KEYWORDS:** *IEEE 802.11, Queuing Delay, Antenna Design and Simulation, Network physical layer simulation***.**

## INTRODUCTION

The present day research is focusing on autonomous devices. Different ad hoc wireless sensor networks need to be incorporated in the design of these devices to make them run autonomously. The field of science and technology has seen an exponential increase in the research and development of wireless sensor networks in the last decade. Looking at the research and development trend, one can expect even greater research in this area.

Wireless sensor network is a network that consists of sensor devices which are used to sense information like (light, voltage temperature etc) and then supply this information wirelessly to a central gateway[1]. The sensor nodes and central gateway form the wireless sensor network system. The central gateway is provided with a wired link where data is processed, analyzed and measured.

Wireless sensors networks (WSN) consist of wireless devices. These devices have sensors which are used to sense within a range, called sensing range, and send the sensed information to a base station also known as nodes. Sensing nodes are usually static but due to the recent applications of WSN the need of these sensors to be mobile is increased, which brings forth a new challenge in the sensor networks for the researchers.

In past few years we have seen an increased interest in the WSN due to their public oriented applications. These networks have several issues at the physical layer, such as range, energy, delay etc, and numerous researchers have examined these issues from different perspectives[2]. But very little work had been done for optimizing these issues using NS-2 simulator.

This paper presents the optimization of the main issues of the physical layer, i.e. the range and power of sensor nodes, by creating a patch antenna. The results are checked and analyzed using NS-2 simulator.

## RELATED WORK

NS-2 is one of the most commonly used network simulators, written in C++ and OTCL and is in use

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since 1990. It has a vast collection of network protocols including ad hoc networks and IP networks. Its presence as an open source simulator makes it an excellent choice for use in academia as well as industry for designing, testing, validating and evaluating new and existing protocols and architectures.

Physical layer performs a number of steps for conversion of data into a format suitable for transmission onto a physical medium. Similarly physical layer is the first layer to play its role on reception of data a the receiving side. Although physical layer of WSN is not completely defined as per standard RFC, as its properties varies from application to application but still a few properties of physical layer are common in all the WSN and these includes choice of transmission frequency, selection of modulation and demodulation techniques, conversion of received electrical waves into bits and vice versa just to name a few. Encryption and decryption phenomenon which are used for security purpose are also the inherent task of the physical layer.

Several researchers have investigated different issues related to the physical layer of wireless sensor networks. The optimization of the energy consumption of WSN is done by increasing the symbol error rate that result in the reduction of transmitted power but at the same time it increases the amount of energy spent on retransmission frames[3]. Thus the transmission power reduction has been carried-out at the expense of increase in the retransmitted energy frames as symbol error rate is increased.

The optimization of layouts of wireless sensor network is done by Kennedy[4]. In this model the connectivity of sensors with high energy node is used to transmit data to the base station and then information is relayed from sensors to the satellite or aircraft. The communication range of the sensors is variable in a limit depending upon the application it is used for.

## METHODOLOGY

In all the networks there is a bunch of different protocols and standards at each layer that are used for carrying-out communication[5]. The layered structure of WSN closely resembles ad-hoc Wireless Networks. The deployment of wireless sensor networks is highly dependent on the given application. Adding to it, the Quality of Service (QOS) parameters, energy requirements per node, geographical conditions and available budget are also the parameters that play a vital role in the deployment of the WSN[6].

NS2 is a simulation tool that can easily and effectively analyze a number of characteristics of the networks and can evaluate their performance. In this work we simulated all the existing layers of wireless sensors network and checked their performance. Range and power are the two major issues faced at the physical layer and a lot of research is going-on now a days to find an optimal solution for these issues. And if these issues get resolved, a big product market, ranging from industrial applications to home usage, is waiting for profitable investment. Wireless Sensor node is very small in size and scope and a large number of these sensors have to be deployed in the area of interest to gather some information for a specific period that may extend from hours to months and years[7]. So the sensor node should have the capability to work for such a long period of time on battery without replacement. The second concern in this regard is range, i.e. the neighboring area where a node can easily communicate with its neighbors. Our design approach is using simulation engine NS2 to simulate each node in distinct thread so that behavior of each node is observed simultaneously with all the other nodes. In this way every node is working independently of the other nodes but at the same time interacting with them as well. In terms of design and flexibility, NS2 outperforms its competitors like JSIM, Glomosim, and Om-NET++.

The range of the antenna depends primarily on two factors antenna design and transmit power. Both these factors are interrelated to eachother. Optimized antenna design can save a lots of transmit power and thus can improve the performance of sensor network many folds[8,9]. In simulating the antenna for wireless sensor networks for our proposed model, there were a number of parameter that were especially cared-for. These include radiation pattern, solid angle, distance between nodes, type of antenna, Theta angle and Phi angle etc. In the implementation phase, first of all simulation codes for a number of patch antenna were written and then performance of the WSN was checked using these antennas at the NS platform.

Implementation of antenna in NS2 requires mentioning the number of nodes and data rate for transport and application layer. The classes were written in C++. However there are different classes defined in NS2 e.g. wireless-phy. These classes have specific and defined parameters and if we call those classes all these parameters are loaded by default in the simulation.

We have used Patch antenna in all the simulation scenarios instead of the default omni-directional antenna. In the next sections, we will analyze in detail the performance of our newly designed antenna and will show how it improves the performance of sensor node in wireless sensor network.

## SELECTION OF ANTENNA

All networks have different protocols, and standards for each layer which should be taken into account when we are designing communication.

The existing antennas meeting the size, bandwidth and other demands of the multimedia sensor networks have been designed mostly for 2.4GHz. They are used to communicate over short distances. Nodes size miniaturization is evolving at five different technological fronts: Antennas, sensory circuits, battery chemistries, digital base band circuits, and RF circuits. But antennas show immune to miniaturization, because the physical laws that determine their behavior cause their basic attributes to be self-conflicting.

## SELECTION OF BEST POSSIBLE ANTENNA FOR WSN

Directional antennas are beneficial for wireless sensor networks, because of increased spatial reuse ratio and reduced energy consumption. They provide angle-of-arrival information, which can be used for routing algorithms and localization in wireless sensor networks. It was found that using directional antennas not only can increase the throughput capacity but also can decrease the delay by reducing the number of hops.

Antennas for wireless sensor networks (WSN) need to satisfy a number of properties additional to those expected from other antennas such as the antenna efficiency. Since there are a number of WSN nodes in every network, low cost of the antenna is important. WSN nodes are small, which means antennas must also be of reduced size. The RF transceiver stage is designed to save power and energy. These were the reasons that inspired us to choose patch antenna for our proposed model.

Patch antenna (also known as a Rectangular Micro-strip Antenna) is a popular antenna type. It consists of a single metal patch suspended over a ground plane. The assembly is usually contained inside a plastic random, which protects the antenna structure from damage. Patch antenna has all those properties which we require in wireless sensor networks. It has a very small size so can be put on a node very easily. It requires less input power and the biggest advantage is that it can be used as a directional antenna as-well.

## OPTIMIZATION OF ANTENNA

Four different types of patch antennas were selected and optimized in antenna magus. In the optimization process each antenna was selected one-by-one and there parameters including feed-line-length, substrate height Patch length etc were changed. After changing these parameters the antenna was redesigned. The same process was repeated until best possible output was obtained. Once the optimized parameters of all the four types of patch antenna were obtained, the antennas were imported to CST studio suite and the gain and directivity parameters of the antenna were analyzed. Their performance is shown in following section. The four types of antennas used in our analysis are discussed in the following lines:

## INSET-FED MICROSTRIP PATCH ANTENNA

This antenna is very popular in microwave frequency range because of their simplicity and compatibility with circuit board technology. The rectangular patch antenna is one of the most commonly used microstrip antenna. Inset-feed microstrip antennas are used in direct integration with microstrip circuits, and can be engraved on the same substrate. These antennas work under a wide range of impedance having no need of extra impedance matching circuit.

The Inset-feed Patch antenna is fed by a microstrip feed line connected to an inset in the patch. By varying the inset distance from the edge of the patch, the input impedance can be controlled. The patch can be seen as a resonant cavity with radiating slots at each end of the patch. The fringing fields extend the effective length of the patch, thus, the length of the half-wave patch is usually less than a half wavelength in the dielectric medium.

## EDGE-FED MICROSTRIP PATCH ANTENNA

Edge-fed patch antennas are usually manufactured by etching the antenna patch element and feed network in a metalized dielectric substrate. Larger antennas are sometimes constructed by bonding metal cut-outs to a bare substrate. An edge-fed patch antenna is fed by a microstrip feed line connected to the edge of the patch. The microstrip feed line usually incorporates a quarter-wave transformer for impedance matching.

## SQUARE TRUNCATED EDGE-FED CIRCULARLY POLARIZED PATCH

Microstrip antennas are simple and inexpensive to manufacture using modern printed printed-circuit technology except perhaps at lower frequencies, where a pair of scissors and some copper tape may be sufficient. There are numerous configurations that can be used to feed microstrip antennas, among them a few are microstrip line, coaxial probe, aperture coupling and proximity coupling. This particular antenna uses a microstrip feed line with a quarter-wave matching section.

The patch antenna is designed so its maximum pattern is normal to the patch element. This can be achieved by proper selection of excitation mode beneath the patch. In rectangular patch, the length of the element is normally between a third and half of a wavelength. Circular and elliptical polarization may be obtained using various feed arrangements or slight modifications made to the elements, with two orthogonal modes excited with a 90° time-phase difference between them. For a square patch, nearly circular polarization may be achieved by trimming the ends of two opposite corners, resulting in resonance along the diagonals.

## ELLIPTICALLY EDGE-FED CIRCULARLY POLARIZED PATCH

Microstrip or patch antennas are popular in the microwave frequency range because of their simplicity and compatibility with circuit board technology. Dual-fed patches may be used to produce circularly polarized radiation but this requires the use of a feed network to provide equal excitations and a 90° phase shift between the ports. The elliptical patch described here has the advantage of using a single microstrip feed connected to the edge of the patch, at 45° to the axes of the ellipse. The elliptical patch is fed with a single microstrip line at 45° to the axes of the ellipse.

In comparison with the notched circular patch, the basic resonant structure in elliptically edge-fed circularly polarized patch is perturbed such that two, spatially orthogonal resonant modes are induced by the single feed. The perturbation is created by adjusting the ratio of the ellipse axes, and is chosen to be sufficiently large to shift the frequencies of the two modes. At the centre point between the two frequencies, the impedances seen by the feed are such that the currents in the two modes are 90 ° out of phase.

## SIMULATION OF ANTENNA IN NS-2

The performance of the protocol was verified on Network Simulator (NS-2)[10]. Various scenarios were tested with MAC 802.11 at the MAC Layer with a simple Propagation Model. Wireless networks of different physical areas with different number of nodes were simulated. These nodes have uniform distribution over the entire region[11]. Depending on different topologies transmission radius can be varied.

Initially different antenna software's (CST Design Environment and Antenna MAGUS) were used to get the best possible antennas for wireless sensor networks. First of all the different types of patch antennas were checked. These antennas were different on the basis of feeding of the patch, input power, size of patch and the output characteristics. We then come up with four different types of patch antennas. The parameters of the antennas were changed to get the optimized output. CST STUDIO SUITE was used to get the radiation pattern of these antennas and their performance was checked.

This graph in Figure 1 shows performance in antenna magus. The value of phi angle is taken as 0° and theta is varied from 0° to 360°. Values of directivity have been taken from Figure 1.

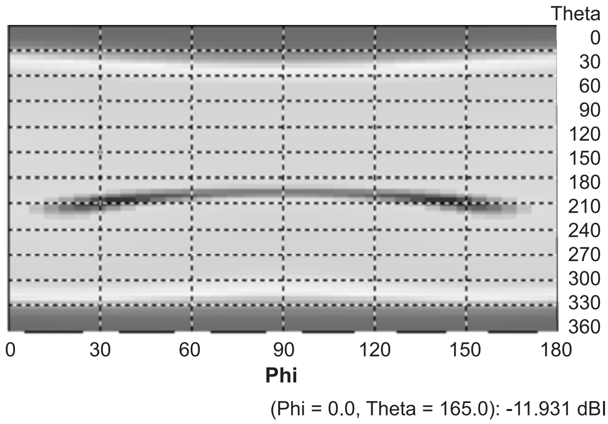


Figure 1. Antenna Performance in MAGUS.

Next the performance of various protocols was analyzed in changing network scenarios using NS2 simulation tool. Simulation tools can give us comparative performance analysis of several alternative schemes. In NS we create different classes for every function and than in that class we make changes to optimize or to get better performance. Here are some graphs showing relationship between different classes which are created for doing all functions as shown in Figure 2.

As shown in Figure 2, sub-classes have been generated from classes for performing rest of tasks. As most of our work was on antenna replacement so different scenarios were created and run our simulated model using the built-in classes in NS-2 for Omni directional antenna.

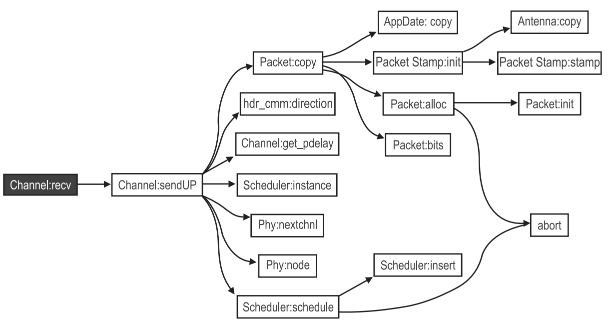


Figure 2. Receiver side implementation in NS-2 showing all the classes

In the proposed model a scenario of eight nodes was created. The results were evaluated for packet flow, delay and throughput parameters. NS2 gives the output in form of trace file and NAM files. NAM files gives visual display of nodes moving randomly and shows packets flowing into and out of each node. The output of the NS-2 are tested and validated as it closely simulates the actual scenario. The record of every event in NS-2 is saved in a trace file. Using trace file we can analyze the results of the proposed model of Adhoc network. GAWK language is used to draw results from the trace file of the NS-2 simulator. The results showed that by replacing the directional antenna with omni-antenna we can achieve a performance improvement in the overall system. An increase in the packet flow rate was observed after implementing the proposed idea into the model.

## PERFORMANCE AND ANALYSIS

For the performance evaluation and analysis of the proposed model we have used NS-2, antenna Magnus and CST Microwave studio softwares. A thorough literature review and study of the existing work in the field was done before doing simulation of the proposed model. The basic aim of the work was to explore the physical layer of the WSN and to contribute a better solution for WSN for its Physical Layer. At the end we come up with a better model of WSN optimized from original physical layer with a directional antenna as we have a major issue of power in sensor nodes so this antenna with optimized directivity will help to save power as it is obvious that with the use of omni-directional antenna, same power is transmitted in all direction but as we don't know that communication is done in a particular direction, so the proposed model solved this inherent issue in the WSN. Another contribution of our work is in the sensing range of the node of the WSN. It is because using a directional antenna due to the concentration of power in the same direction increases range of the node which inturn increases the reachable neighbours of the WSN and thus improves the overall efficiency of the network[12].

## CONCLUSION AND FUTURE WORK

Our work has opened a new way for researchers by looking into the performance of the WSN by optimizing the antenna. Using our technique one can optimize any network by optimizing its antenna like zigbee, ad hoc networks or any other wireless network. Presented methodology is an optimization scheme which can make a better use of the available resources and improved results can be obtained using same available resources. Due to its wide application in various wireless devices, our work can easily be expanded and applied to any other network. NS2 tool is very useful in the sense that it can test any network performance by changing the different parameters in the soft format.

Our work has exercised a little different approach in the sense that most of research going in communication field now a days ends-up with improved results either by changing parameter of existing routing protocols, or using some power saving mechanism by making some nodes to sleep when there is no active transmission or by changing the modulating techniques and using higher modulation schemes to make one symbol carry more number of bits. But all these methods are one way of optimization. We tried to show that other than doing these changes in the basic model of the system there is another way to tackle the problem i.e. to work directly on the physical parameters of the nodes in the WSN like antenna type and its various parameters. Other physical parameters like material of the antenna might be another area to work-on. Similarly the placement of nodes (relative position) can also play a vital role in the overall system performance.

Our work can be further extended to other antennas beside Patch antenna. The proposed technique can help to understand antenna functioning in an environment where a lot of nodes are communicating at the same time. By relating antenna and networks at the same platform of ns2 will help the antenna design engineer to design more appropriate antenna for given network by looking into its performance in the actually deployed network conditions.

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