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# Spatial And Temporal Characterization Of 433mhz Radio Base Wsn In Outdoor Environment

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**ABSTRACT:**In this paper 433MHz radio (KYL500s) based Wireless Sensor Network (WSN) is used in an experimental testbed to investigate spatial and temporal variations of the packet error rate which is a wireless link quality metric in order to determine the link quality. The packet error rate measurements were taken at intervals of 10 meters up to a distance of 600meters in 0°, 90°, 180° and 270° directions and the results obtained show that the packet error rate increases with distance. The experimental WSN was set up for the whole day and the measurement of packet error rate variation with time was taken at fixed wireless sensor distances of 50meters, 100meters, 150meters, 200meters, 250meters, 300meters, 350meters, 400meters,450meters,500meters, 550meters and 600meters from the sink. The temporal result showed that the link quality is worse at approximately 10.00 and 17.00 hours period.

## I INTRODUCTION

The propagation of radio signals is affected by several factors such as noise, interference and multipath distortion that contribute to the degradation of its link quality. The effects of these factors are even more severe especially for wireless sensor networks (WSN) due to their inherent low power requirement. Wireless Sensor Networks (WSN) consist of potentially large tiny sensor nodes, which are capable of sensing the parameters of interest, processing the data locally and communicating the processed information over the radio. The quality of the communication links is a function of many variables including distance, direction and time [1].Quality of communication links has a significant impact on the performance metrics of wireless sensor networks such as network lifetime, network throughput and reliability. The quality of the wireless sensor link can be estimated through the following parameters namely: Received Signal Strength Indicator (RSSI), Packet error rate (PER) and Link Quality Indicator (LQI) .Many sensor nodes provide direct reading of these parameters and they can be taken as metrics to evaluate the link quality. In addition the link quality depends on the radio transceiver used in the wireless sensor node. In order to deploy a wireless sensor network efficiently and maintain a stable communication over time, the link quality characteristics must be investigated deeply [2]. Wireless sensor link quality can be estimated by determining the spatial and temporal variation with the link quality metrics. Wireless sensor link quality is not a fixed quantity, even though the distance between the nodes is unchanged, it varies over the time due to fading. The causes of fading are the multipath reflections from the obstacles present in the surrounding and the interference from other sources. Link quality varies in outdoor environments due to the environment characteristics, such as climate conditions (e.g., temperature, humidity), human presence, interference and obstacles. Determining the spatial and temporal dependence of the link quality in outdoor environment will indicate the best placement of the nodes to be used to achieve a certain transmission success rate from the sensor nodes. An experimental testbed was used to determine how the link quality metric packet error rate varies spatially and temporally in KYL500s radios based wireless sensor nodes. The wireless sensor network used in the testbed consists of a wireless sensor nodes and the sink which is used to receive data from the sensor node. The wireless sensor nodes would be equipped with acceleration sensor 3 axis MMA 7361(model: 1156) and liquid flow sensor (model: 3904). The wireless sensor nodes and the sink are custom made and both will use KYL500s transceivers.

## II LITERATURE REVIEW

From the results published in literature [3, 4, 5, 6] wireless communication is known as unstable and unpredictable since the quality of a wireless link may vary significantly over time or with slight displacement. In WSN, the radio transceivers transmit low power signals which make radiated signals more prone to noise, interference and multipath distortion. The low power transceivers rely on antennas with non ideal radiation patterns, which lead to anisotropic behaviour [4].

The effects of these factors are even more significant on the propagation of wireless signals with low-power radios, typically used in Wireless Sensor Networks (WSN) [1]. WSN have severe constraints on energy consumption since nodes have to survive on limited battery energy for extended periods of time [5]. There is need to determine the link quality of the wireless sensor networks (WSN) to know what is expected of the link and to maintain reliable communication between nodes in the wireless sensor network (WSN). When deploying wireless sensors into a target field, information about how wireless sensors perform at various distances and orientations relative to each other will make optimal placement easier [6].

The authors in [7] investigated the spatial variation of link quality metrics LQI and PER using wireless sensor nodes that are randomly distributed and they developed empirical models of the LQI and PER as a function of distance using regression analysis. Their result showed that empirical models with quadratic function had a very poor quality fit and empirical models with power function performed even worse. The research work [7] did not consider the temporal effects on the link quality and the wireless sensors nodes they used has range 30meters therefore multi-hop communication are used by the sensors to communicate with sensor outside this range.

In[6] packet loss ratio (PLR), RSSI, and LQI are measured as a function of distance, angle, and transmit power, while taking environmental conditions (fog and rainfall) into consideration using Tmote Sky motes . The results from [6] shows that many wireless sensor nodes have radios that claim to be omnidirectional, meaning they can transmit equally in all directions but this claim is not completely accurate, as the antennas have weaker and stronger reception areas in three dimensional space. Their results showed that packet loss rate increases with distance and is not symmetrical in three dimensional space.

In [9] the authors measured the Packet Received Rate (PRR) against the distances in a uniform grid WSN. They discovered that both the mean link quality and the variance in quality were a function of distance. They conducted an evaluation to compare RSSI and LQI with second generation chips (CC2420). Their preliminary results indicated that RSSI for a given link had very small variation over time for a link. Also, the behaviour changes depending on the link considered and also there is a linear correlation between the two estimators and the distance: both LQI and RSSI decrease as the distance to the base station increases.

In [10] the researchers used a stationary network and the profile of each link were determined through taking many measurements throughout a day or several days using CC2400 sensor. Their results showed that the link quality metrics RSSI and PER vary little with time. Although the maximum range they consider is 30 meters.

## III TEST BED DESCRIPTION

The field in front of the professor Festus Aghagbo Nwako library building of Nnamdi Azikiwe university, Awka , Anambra state, was used as the testbed. The Global Positioning System (GPS) coordinates of the testbed is latitude N6° 14.8753ˈand longitude E7° 6.9283ˈ.The reason for the choice of this testbed location was that it is spacious and the testbed covers the range of the radio (600 meters) in all directions. One of the wireless sensor nodes was designed to function as a sink and was attached to a laptop. The sink was used to gather data from the wireless sensor node and monitoring the link quality. The wireless sensor nodes were equipped with accelerometer and flow rate sensor. But during the experiment random known test packets were sent by the sensor node instead of the actual sensed value. The Packet Error Rate (PER) could be read from the WSN Graphic User Interface (GUI) on laptop in which the sink was connected.

## IV RESEARCH METHODOLOGY

During packet error rate measurement, the wireless sensor node used was configured using the C program so that the wireless sensor node generates one thousand random packets called test packets and they were transmitted by the wireless sensor to the sink which was connected to the laptop instead of the actual data sensed by the wireless sensor. Both the wireless sensor node and the sink have a copy of the test packets. Each time the sink receives the test packets sent by the wireless sensor node it will compare the received test packets with the original copy it has. The test packets are of the same format with actual packets used by the wireless sensor node to send the actual sensed values (flow rate, vibration, sensor battery and time). The purpose of using the test packets is to easily detect the errors in received packets. If the actual sensed values of the wireless sensor were used there will be no means of detecting the errors in received packets since the wireless sensor does not employ any error detecting and correcting scheme.

## V SPATIAL MEASUREMENT

To evaluate spatial dependency of link quality the measurements were taken on the four cardinal directions covering 360 degrees. The north of the compass used was taken as the reference point (0 degree), and then the subsequent cardinal points (90 degree, 180 degree, and 270 degree) were assigned in clockwise manner. This setup enabled us to investigate effects of both distance and direction on the communication link quality. The sink was connected to the laptop which was put at the centre of the testbed and the wireless sensor nodes were positioned at any of the cardinal points. The measurement of the spatial variation of the WSN Packet Error Rate (PER) was taken once every month for a period of six months. The date of the month the measurement was taken was selected using simple random sampling. The reason was to ensure that each dates in the month has equal probability of been selected.

The distance of the wireless sensor nodes from the sink were increased gradually and the value of the Packet Error Rate (PER) was taken at every ten meters. At each point the packet error rate was allowed to stabilize before the reading was taken. The variation of the link quality with distance which is indicated by the Packet Error Rate (PER) was measured in each of the cardinal points up to 600 meters which is the maximum range of the KYL500s transceiver when the data rate is 9600bps. The measurements were taken for several days and the average was used to ensure statistically significant results and indirectly account for the effects of weather variation. To ensure that fluctuation of the wireless sensor node voltage did not affect the spatial measurement, wireless sensor node voltage was maintained at 9 volts during the entire spatially measurement by using rechargeable 9 volts dry cell battery which was recharged at intervals to maintain this voltage level. Then Matlab program was used to plot the graph of the mean packet error rate against distance.

## VI Temporal measurement

The experimental wireless sensor network (WSN) test bed was set up in for a whole day (24 hours). The wireless sensor node was at a fixed distance form sink. The link quality metric which was indicated by the Packet Error Rate (PER) was taken every one hour interval for the whole day. The experiment was conducted when the wireless sensor node is at fixed distances of 50meters, 100meters, 150meters, 200 meters, 250meters, 300meters, 350meters, 400 meters, 450 meters, 500 meters, 550 meter and 600 meters from the sink. The measurements were taken for several days and the average was used to ensure statistically significant results and to indirectly account for the effects of weather variation. To ensure that fluctuation of the wireless sensor node voltage did not affect the temporal measurement, sensor node voltage was maintained at 9 volts during the entire temporal measurement by using rechargeable 9 volts dry cell battery which was recharged at intervals to maintain this voltage level. Then Matlab program was used to plot the graph of the packet error rate against time to depict graphically illustration of WSN link quality temporal variation.

## V RESULT DISCUSSION

The range of the spatial measurement was 600 meters which is the maximum range of KLY500s when operating at data rate of 9600bps.Matlab program was used to determine the correlation between the mean packet error rate and distance. The correlation value is 0.9334 this means that the average packet error rate increases with increase in the distance between the sensor node and the sink. Thus wireless sensor node deployed farther from the sink experienced more packet errors than those nearer to the sink. Also the packet error rate values at the same distances may differ in different directions. Matlab program was used to plot the mean packet error rate against distance. The plot of the mean packet error rate against distance is shown in Figure 1, as expressed by the graph, the mean Packet Error Rate (PER) increases with increase in distance. This means that as distance of the wireless sensor node increases from the sink the link quality which was estimated by the packet error rate would worsen.

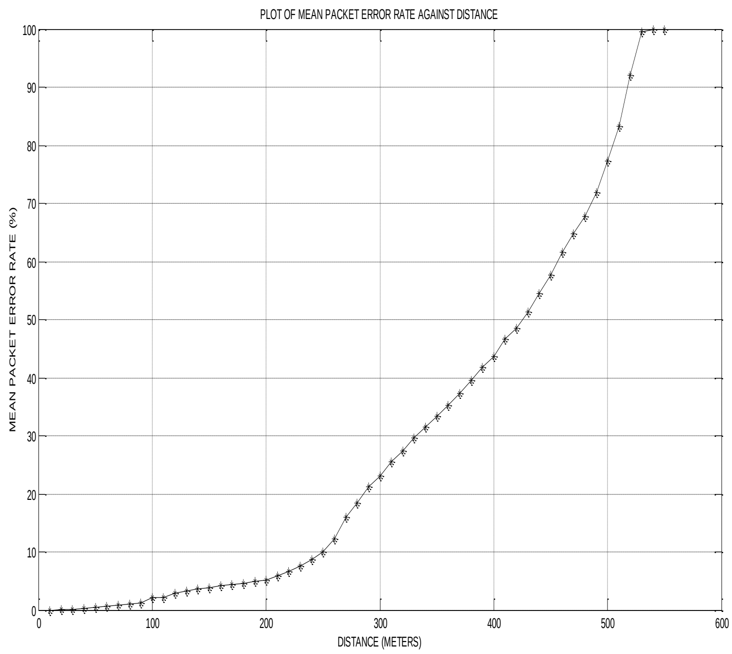


Figure 1: Plot of Mean packet error rate against distance

For the temporal variation of the packet error rate at fixed distance of 600 meters no signal was received by the sink from the wireless sensor nodes during the period the measurement was carried out. For the other fixed distances consider in the temporal variation of the packet error rate, there was an improvement in the link quality during the night and early in the morning except for the test distance of 550 meters in which the packet error rate was constant. The packet error rate reached its peak approximately during 10.00 to 17.00 hours period across all the fixed distances of 50meters, 100meters, 150meters, 200 meters, 250meters, 300meters, 350meters, 400 meters, and 500 meters used for the packet error test as shown in the graphs in Figure 2, Figure 3, Figure 4,Figure 5, Figure 6, Figure 7, Figure 8, Figure 9, Figure 4.10, Figure4.11. The Matlab program in the Appendix E was used to plot the temporal variation of the packet error rate for each of the distances 50meters, 100meters, 150meters, 200 meters, 250meters, 300meters, 350meters, 400 meters, and 500 meters.

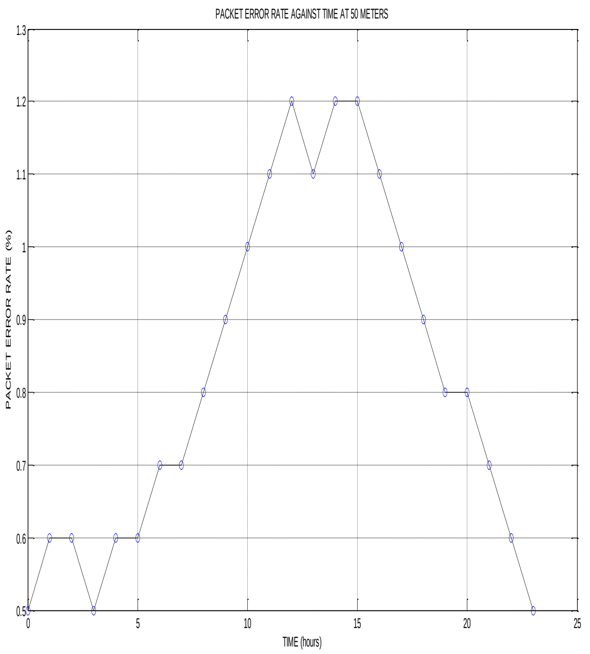


Figure 4.3 Plot of packet error rate against time at 50 meters

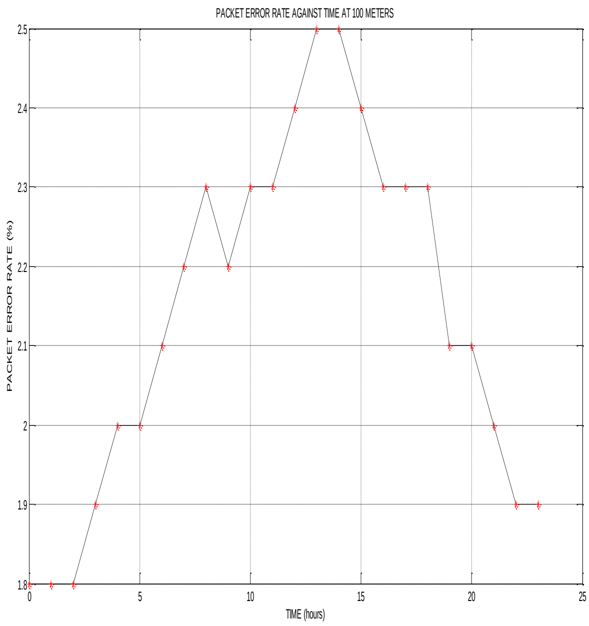


Figure 4.3 Plot of packet error rate against time at 100 meters

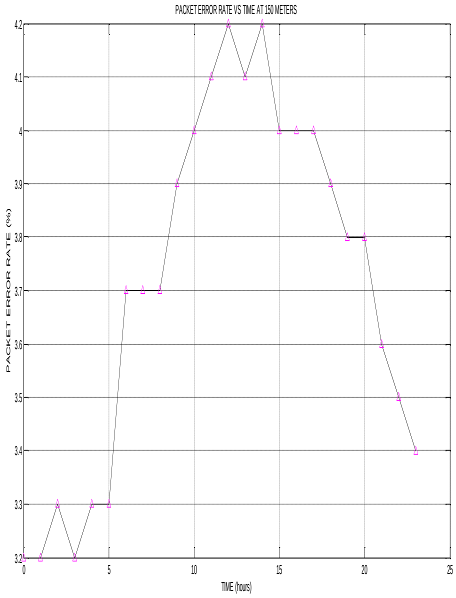


Figure 4.5 Plot of packet error rate against time at 150 meters

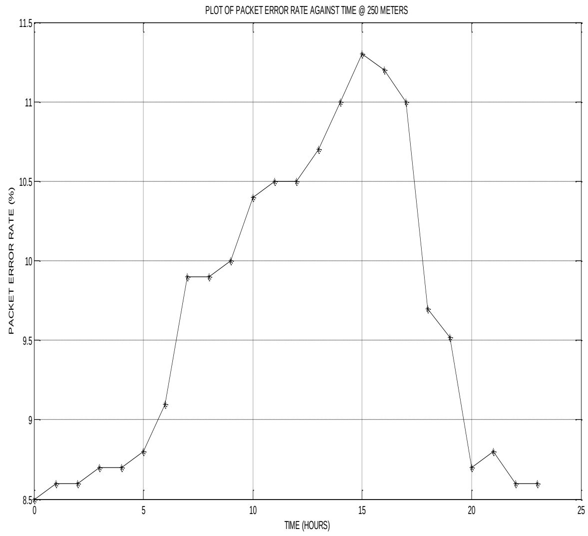


Figure 4.6 Plot of packet error rate against time at 250 meters

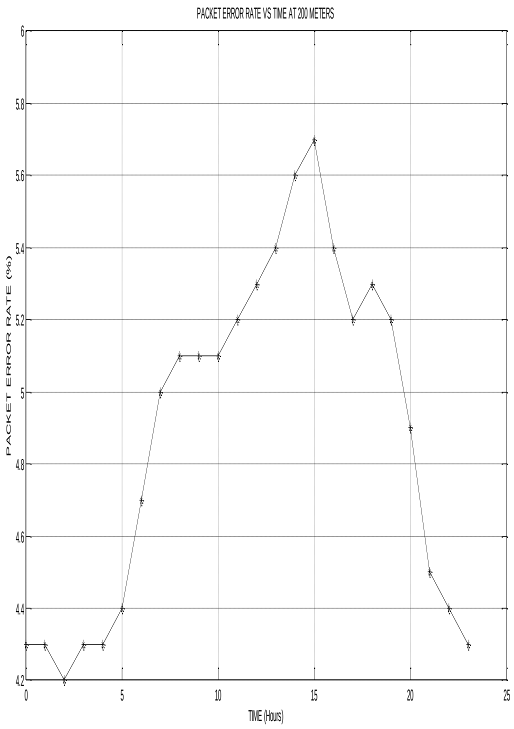


Figure 4.6 Plot of packet error rate against time at 200 meters

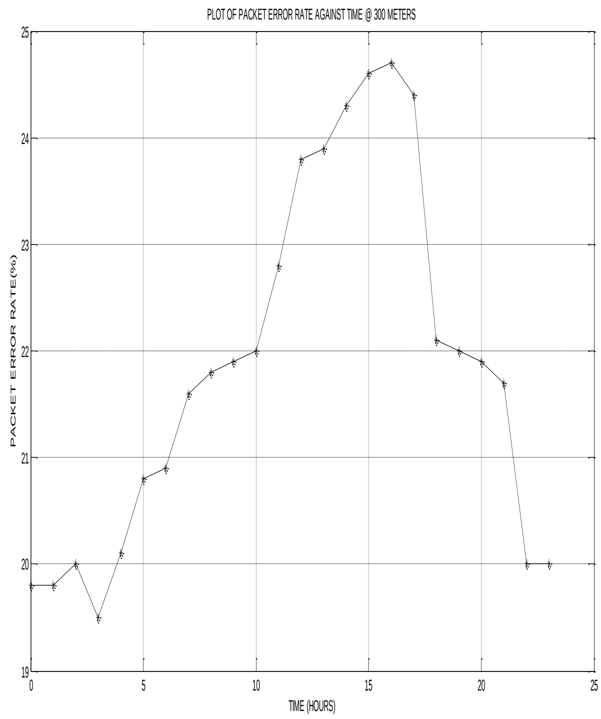


Figure 4.6 Plot of packet error rate against time at 300 meters

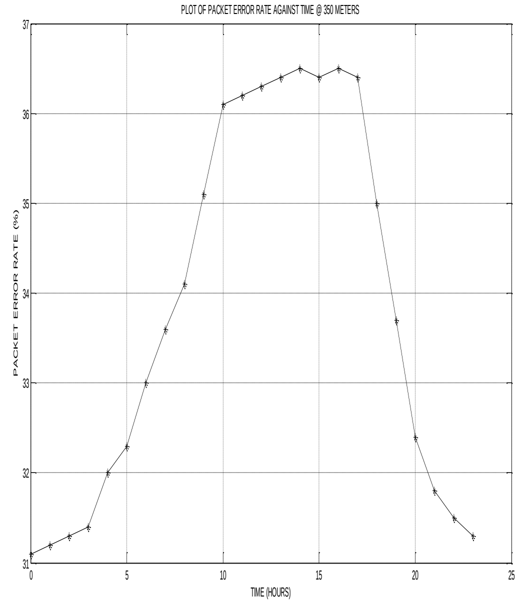


Figure 4.6 Plot of packet error rate against time at 350 meters

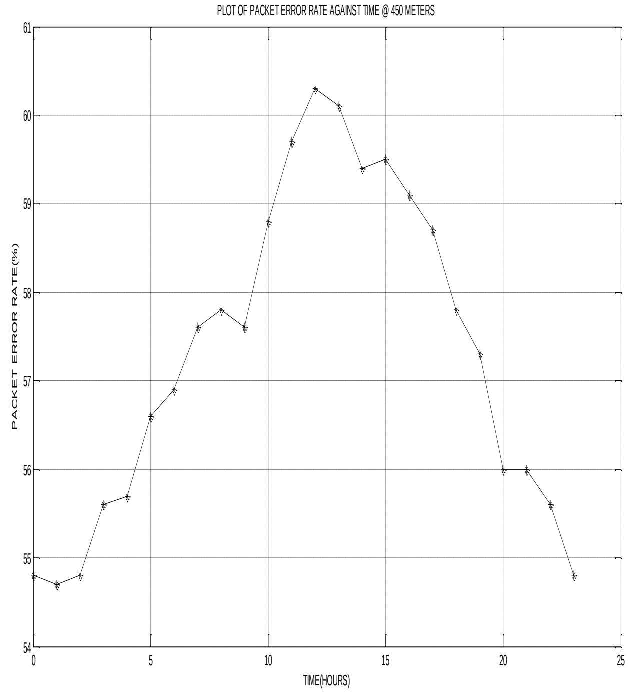


Figure 4.10 Plot of packet error rate against time at 450 meters

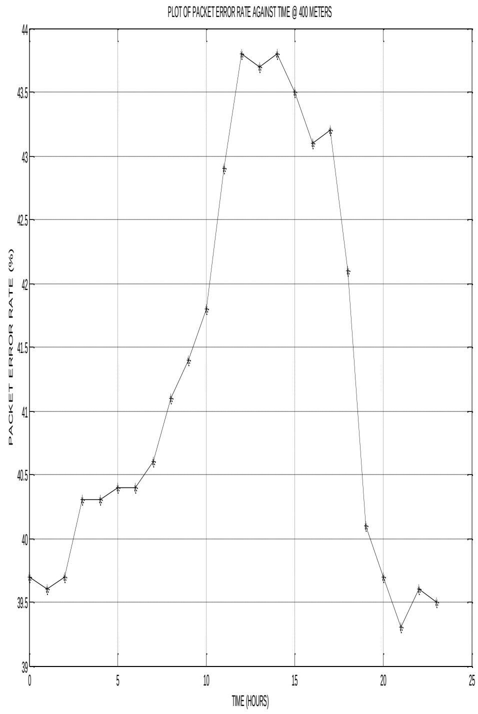


Figure 4.10 Plot of packet error rate against time at 400 meters

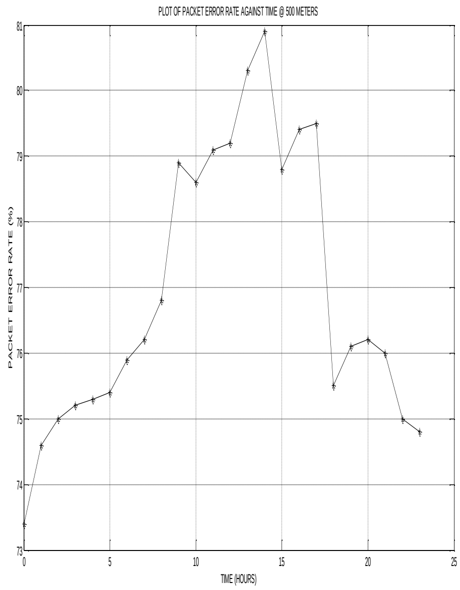


Figure 4.10 Plot of packet error rate against time at 500 meters

## VI CONCULSION

In this research work an experimental testbed was set up to investigate the spatial and temporal variation of the packet error rate which is a link quality metric. The summary of the results obtained shows that the packet error rate increases as the distance of the wireless sensor node from the sink increases. The packet error rate is not stable, it varies with time when the wireless sensor is at fixed distance from the sink and reaches its peak during 10.00 and 17.00 hours period. The results of this experiment can be used to determine the period of the day the packet error rate is at its peak and also to optimal spacing for the wireless sensor to achieve optimal performance.

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