ARTIFICIAL NEURAL NETWORK APPLICATION FOR ERROR ESTIMATION IN WIRELESS SENSOR NETWORK

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Abstract - This paper comes up with an error estimation model for Wireless Sensor Nodes,, the integrity of data received after transmission within a signal coverage range less or equal to 45 meters is analysed, Neural Network linear regression method was used to evolve resolve equation that compares error with weight of data received as $\delta e(w)$ against δw_{ij} , an equation for error rate was also evolved after carefully comparing between data packet transmitted and Packet received, error rate e_r for sensor node was calculated to be 0.00918 thereby establishing the fact that expected packet to be received for every data transmitted is the product of e_r and Packet Transmitted.

Keywords - Packet, Data, Neural Network, Wireless Sensor Nerwork

I. INTRODUCTION

Wireless sensor networks (WSNs) consist of the following set of sensor nodes that can communicate with each other; sensors that measure a desired physical quantity; and the system base station for data collection, processing, and connection to the wide area network. Modern wireless sensor nodes have microprocessors for local data processing, networking, and control purposes [1,5]. WSNs have enabled numerous advanced monitoring and control applications in environmental, biomedical, and numerous other applications. Sensors in such networks have their own dynamics (often-nonlinear), and modeling such a sensor network is often not trivial. Because recurrent neural networks (RNNs) consist of interconnected dynamic nodes, we explore their similarities with WSNs and exploit those similarities in WSN modeling. This paper presents the modeling of WSNs using a forward propagating RNN.[4]Wireless Sensor Networks (WSNs) are characterized by collaborative information transmission from multiple sensor nodes observing a physical phenomenon [1]. Compare to conventional network systems, WSN can be applied to more wide range of regions, such as forest, valley, farmland, and so on. [5]One of the main challenges in adoption and deployment of wireless networked sensing applications is ensuring reliable sensor data collection and aggregation, while satisfying the low-cost, low-energy operating constraints of such applications. A wireless sensor network is inherently vulnerable to different sources of unreliability resulting in transient Failures However, for high error rate of wireless channel and severe energy constraints of battery-powered sensor nodes, the implementation of WSN is a challenging task. The average bit error rate (BER) of wireless channel fluctuates widely, varying from 10^{-6} to 10^{-1}, to recover error packets, there are two basic methods: Automatic Repeat Request (ARQ) and Forward Error Control (FEC). ARQ supposes a receiver will acknowledge a message from a sender, and the sender will retransmits the message if it is not acknowledged within a certain time. FEC uses redundant information along with the data bits to recover the damaged packets, as no acknowledgements are sent to the original sender, the packet will be lost when the error is uncorrectable. Since, in wireless sensor networks, packets are commonly broadcast over shared channel and forwarded over multiple hops, using FEC is preferable because it can reduce the need to retransmit data packets, thereby reducing the power consumed in the process [1,2]

However, such devices are vulnerable to various sources of errors Hence, providing reliable data collection and aggregation has become paramount concern for deploying such sensor applications.

A wireless network of sensor nodes is inherently exposed to various sources of unreliability, such as unreliable communication channels, node failures, malicious tampering of nodes and eavesdropping. The sources of unreliability can be classified into two categories.[1]

Soft failures occur in wireless channels as transient errors, caused by noise from various sources, such as thermal noise at the receiver, channel interference and multi-path fading effects and electromagnetic interference.[4\

II. DESIGN METHODOLOGY

This work adopts the neural network application using the forward propagation method the sensing nodes are referred to as Reduced Functional Device this include the source node and the intermediary node while the FFD which is referred to Full Functional Device is is the Final sink node, where all data converges and are collected for further processing. We come up with a design where the data is a function of weight w and input value x

X_1- W_1
X_2 – W_2
.   .
.   .
X_n– W_n

A forward propagation technique will require a transition for the neural set for inter-node communication, considering the values of x as input value and w as weight.

We therefore express the process of data transmission between nodes as

$X_{11}W_1$- $X_{12}W_2$–. X_{13} W_3 ………………...X_1nWn
$X_{21}W_{1}$.- $X_{22}W_2$– X_{23} W_3 ……………...…...,X_2nWn
$X_{31}W_{1}$.- $X_{32}W_2$– X_{13} W_3 …….……..……...X_3nWn 1
.   .
.   .
.   .
$X_{m1}W_1 – X_{m2}W_2 – X_{m3}W_3$ ....X_nW_n

In this work we refer to reduced functional device RFD as the source and intermediary node which is the input and the full functional device FFD as the sink, we therefore substitute the input x in the neural set as R while FFD is substituted for F.

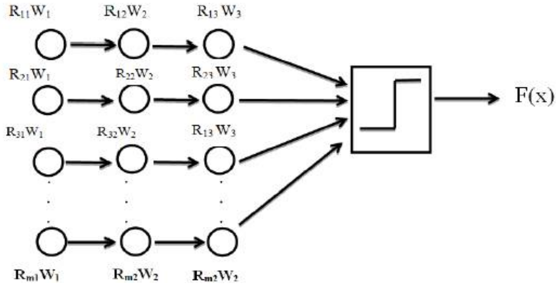


Fig. 1 Recurrent Neural Network Model for WSN

R = RFD
F = FFD
we refer data from RFD as R
X = R
$R_{11}W_1$ - $R_{12}W_2$ – R_{13} W_3 ………………...R_1nWn
$R_{21}W_1$ - $R_{22}W_2$ – R_{23} W_3 ………………...R_2nWn
$R_{31}W_1$ - $R_{32}W_2$ – R_{13} W_3…………………..R_3nWn
.   .
.   .
$R_{m1}W_1 – R_{m2}W_2 – R_{m3}W_3$ ....$R_{mn}W_n$

Fig. 2 Neural Network linear model

The neural set above directly substitute x for R the matrix represent the solution for the equation in figure 2

$$\begin{bmatrix} R_{11,} & R_{12} & R_{13} & \dots & R_1n \\ R_{21} & R_{22} & R_{23} & \dots & R_2n \\ R_{31} & R_{32} & R_{33} & \dots & R_3n \\ \cdot & \cdot & & & \\ \cdot & \cdot & & & \\ \mathbf{R_{m1}} & \mathbf{R_{m2}} & \mathbf{R_{m3}} & \dots & \mathbf{R_{mn}} \end{bmatrix} \cdot \begin{bmatrix} W_1 \\ W_2 \\ W_3 \\ \\ \\ W_n \end{bmatrix} = \begin{bmatrix} F_1 \\ F_2 \\ F_3 \\ \\ \\ F_n \end{bmatrix}$$

Fig. 2 Neural Network Matrix for WSN

The Matrix in the equation which can then be expressed as logistic regression.

Note this model is only implementable when the addressing mode is perfect for a linear routine process.

the neural network will look like this, it is a feed forward , the first column is the input R with its corresponding weight W , followed by the repeater node which is referred to as intermediate node, they could also be termed as hidden layers, which ranges between 1,l and L.

$1 \leq l \leq L, layers$

which can be represented with a black box

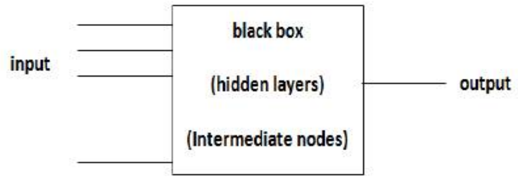


Fig 3 Black box for hidden layers(intermediary node)

This is logistic regression they have the same structure like the linear model, where we have the input combined linearly using weight sum up into a signal which passes soft threshold. The eventual equation becomes

$F(R) = F_{NN}(R-1),y(R-2),y(R-3)\dots y(R-n)$....... (2)

The idea is to evolve an equation to compute for data packet error between transmitted node and receiving node. Data loss occurs when one or more packets of data travelling across the node and fail to reach their destination. the equation draws a relationship between the source node and the sink node which is recursed in equation 3 .

$F(R) = \sum_{i=1}^{n} Fi(Rn)$ .... (3)

A linear model is proposed, which is logistic regression where we have input combined linearly using weight which sum up to signal, this model is meant to implement a genuine probability, error measure which will be based on likelihood measure given below

$\prod P(F_{n|} R_n) = \prod_{n=1}^{n} \theta\ (F_{n-1}w^T + R_n)$ .... (4)

P is the probability of error and is maximised between output F, and input R and then derive error measured as weight W becomes

$$w_{ij}^{i} = \begin{cases} 1 \leq l \leq L, layers \\ 0 \leq i \leq d(i-1)\ inputs \\ i \leq j \leq x\ output \end{cases} \text{........(5)}$$

L = layers
d= dimension
j= output

Note w refer to data weight

$R_j^{(i)} = \Theta(S_J^{(i)} = \Theta(\sum_{i=0}^{d(i-1)} \sum_{ij}^{i} w_{i=0}^{(i)} R_i^{i-1})$ .... (6)

The operation of the above equation shows how new value of input R is gotten from previous R. The process is recursive.[3]

Θ =tanhh(s)

All weight are represented by $w = w^{ijl}_{i}$

error between transmitter and receiver can be defined as

$e_{ij} = (d_{ij} - \sum_{k=1}^{k} R_{ij}\ R_{ij}$ ....(7)

i = row

for equation e_{ij} , j= column

R stands for receiving and transmitting node

d is the range between transmitted and received data

To find error measurement

We can evaluate $\delta e(w)/\delta w^{i}_{ij}$

one by one analytically or numerically

$\nabla e(w) = \delta e(w)/\delta w^{i}_{ij}$......... (8)

a trick for efficient commutation is the product rule

to solve for equation 8

we apply product rule

$\delta e(w)/\delta w^{i}_{ij} = \delta e(w)/\delta s_j i \times \delta s_j i/\delta w^{i}_{ij}$ ....(9)

this is the estimate error between two nodes

the diagram is an illustration of the transmission process, in between are intermediary nodes though not shown.

S_J = Signal

Wij = weight

For every data transmitted between two sensor ,we can compute the error in data transmitted and can be routed between one node from layer $L_{(i=1)}$ to $L_{(i=n)}$, layer L represent various layer of inter-sensor node between the source and the sink.[3]

Which can be represented by

$L = \sum_{i=0}^{n} L$......... (10)

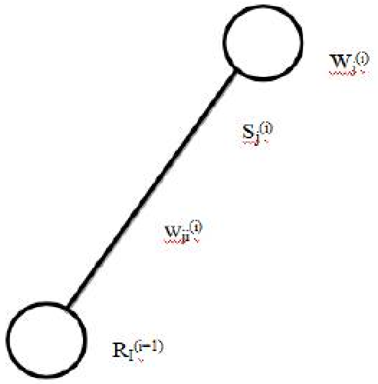


Fig. 4 Layer representation in NN Model

To compute for data error for sensors that are inter linked wirelessly from source node through intermediary node to the sink node we advance the formular in equation 11

$\delta e(w)/\delta w^{i}_{ij} = \delta e(w)/\delta s_j i \times \delta s_j i/\delta w^{i}_{ij}$ (11)

this formular will compute for error

$= \frac{\delta e(w)}{d\delta wij}$

this formular will be applied to calculating errror[3]

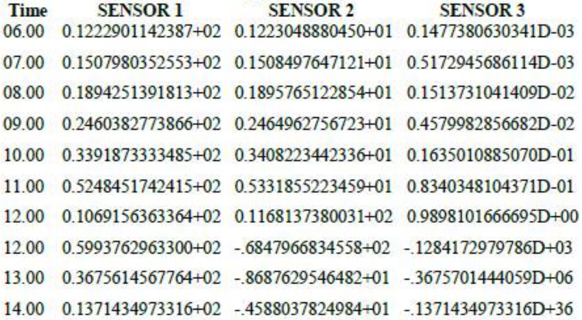
note rhat

12000 bits = 1500 bytes

1500 bytes = payload in a packet

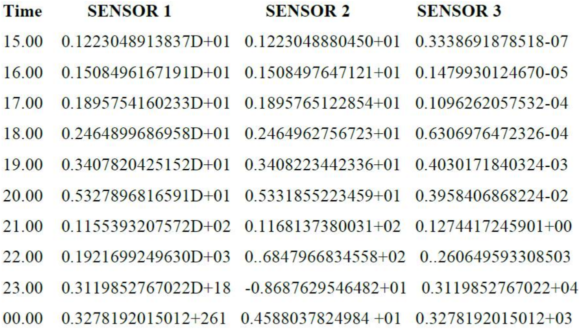
Table 1 and 2 are result of data obtained from sensors nodes at different time of the day.

Table I Data collection via Sensor node Day 1
DAY 1 (FEBRUARY 2ND. 2012)
Temperature



Time	SENSOR 1	SENSOR 2	SENSOR 3
06.00	0.1222901142387+02	0.1223048880450+01	0.1477380630341D-03
07.00	0.1507980352553+02	0.1508497647121+01	0.5172945686114D-03
08.00	0.1894251391813+02	0.1895765122854+01	0.1513731041409D-02
09.00	0.2460382773866+02	0.2464962756723+01	0.4579982856682D-02
10.00	0.3391873333485+02	0.3408223442336+01	0.1635010885070D-01
11.00	0.5248451742415+02	0.5331855223459+01	0.8340348104371D-01
12.00	0.1069156363364+02	0.1168137380031+02	0.9898101666695D+00
12.00	0.5993762963300+02	-.6847966834558+02	-.1284172979786D+03
13.00	0.3675614567764+02	-.8687629546482+01	-.3675701444059D+06
14.00	0.1371434973316+02	-.4588037824984+01	-.1371434973316D+36

Table II Data collection via Sensor node Day 2
DAY 2 (FEBRUARY 3RD. 2012)
Moisture content



Time	SENSOR 1	SENSOR 2	SENSOR 3
15.00	0.1223048913837D+01	0.1223048880450+01	0.3338691878518-07
16.00	0.1508496167191D+01	0.1508497647121+01	0.1479930124670-05
17.00	0.1895754160233D+01	0.1895765122854+01	0.1096262057532-04
18.00	0.2464899686958D+01	0.2464962756723+01	0.6306976472326-04
19.00	0.3407820425152D+01	0.3408223442336+01	0.4030171840324-03
20.00	0.5327896816591D+01	0.5331855223459+01	0.3958406868224-02
21.00	0.1155393207572D+02	0.1168137380031+02	0.1274417245901+00
22.00	0.1921699249630D+03	0..6847966834558+02	0..260649593308503
23.00	0.3119852767022D+18	-0.8687629546482+01	0.3119852767022+04
00.00	0.3278192015012+261	0.4588037824984 +01	0.3278192015012+03

Note that

Packet loss = Packet sent - Packet receive

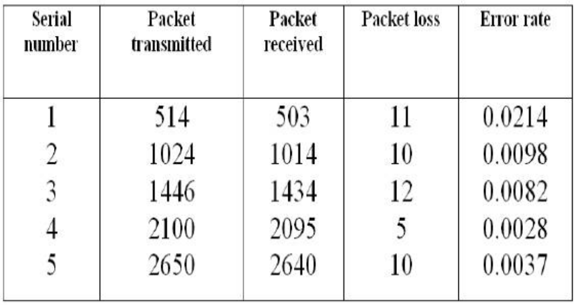
we come up with Error rate

equation 12 will estimate data error between transmission and reception

$Error\ rate = \sum_{t=1}^{n} \left(\frac{Error}{n} \right)$.............(12)

From the calculation based on equation 12 the error rate calculated was 0.00918

Table III Packet transmitted and Packet received



Serial number	Packet transmitted	Packet received	Packet loss	Error rate
1	514	503	11	0.0214
2	1024	1014	10	0.0098
3	1446	1434	12	0.0082
4	2100	2095	5	0.0028
5	2650	2640	10	0.0037

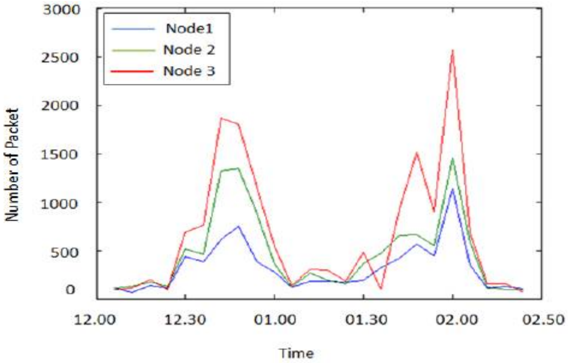


Fig 5 Graph of different node sending packet

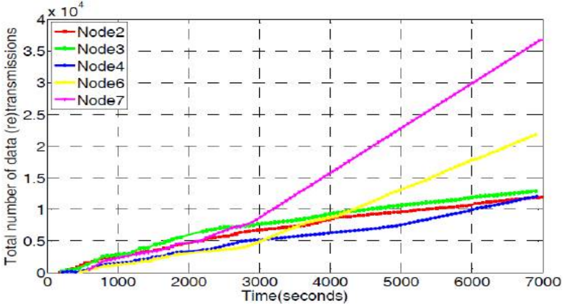


Fig. 6 Number of Data retransmitted by different nodes

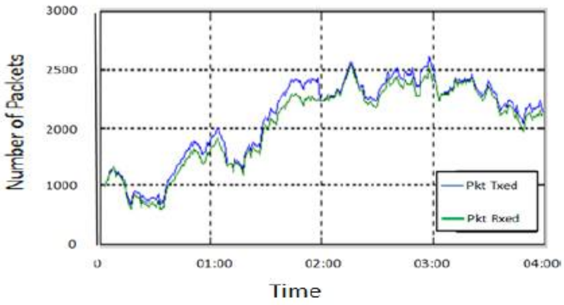
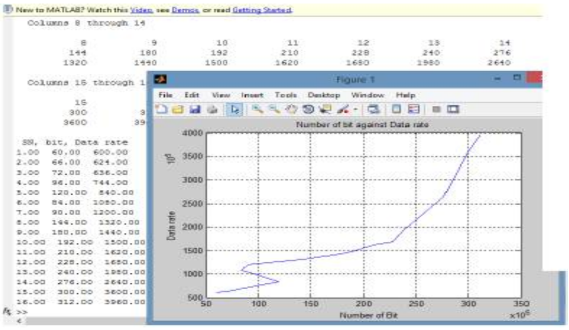


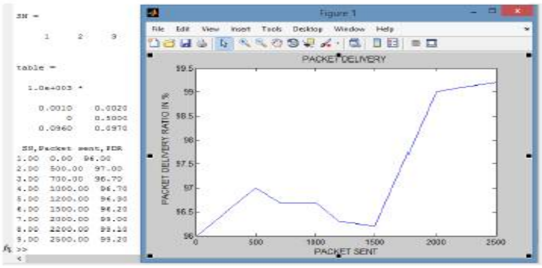
Fig 7. Graph of packet transmitted and received

Pkt stands for Packet
Txed stands for Transmitted
Rxed stands for Received



```
  Columns 8 through 14

         8           9          10          11          12          13          14
       144         180         192         210         228         240         276
      1320        1440        1500        1620        1680        1980        2640

  Columns 16 through 1

        16           9
       300
      3600          39

 SN, bit, Data rate
1.00   60.00   600.00
2.00   66.00   624.00
3.00   72.00   636.00
4.00   96.00   744.00
5.00   120.00   840.00
6.00   84.00   1080.00
7.00   90.00   1200.00
8.00   144.00   1320.00
9.00   180.00   1440.00
10.00   192.00   1500.00
11.00   210.00   1620.00
12.00   228.00   1680.00
13.00   240.00   1980.00
14.00   276.00   2640.00
15.00   300.00   3600.00
16.00   312.00   3960.00
fx >>
```

Fig.8 Graph showing Data rate against number of bits



```
SN =

     1     2     3


table =

  1.0e+003 *

    0.0010    0.0020
         0    0.5000
    0.0960    0.0970

 SN,Packet sent,PDR
1.00   0.00   96.00
2.00   500.00   97.00
3.00   700.00   96.70
4.00   1000.00   96.70
5.00   1200.00   96.30
6.00   1500.00   96.20
7.00   2000.00   99.00
8.00   2200.00   99.10
9.00   2500.00   99.20
fx >>
```

Figure 9 Packet Delivery ratio against Packet sent

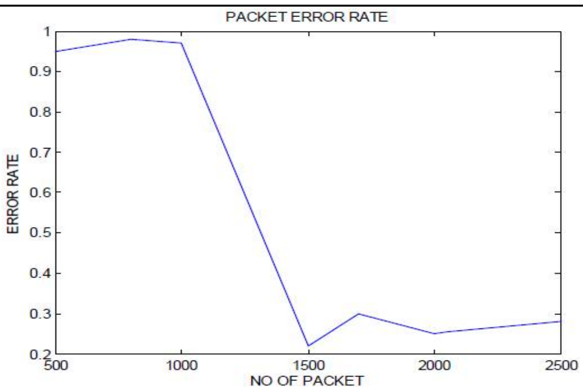


Figure 10 Error rate against Number of packets

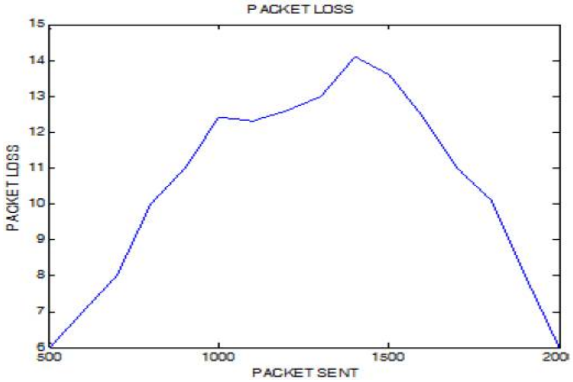


Figure 11 Packet loss against packet sent

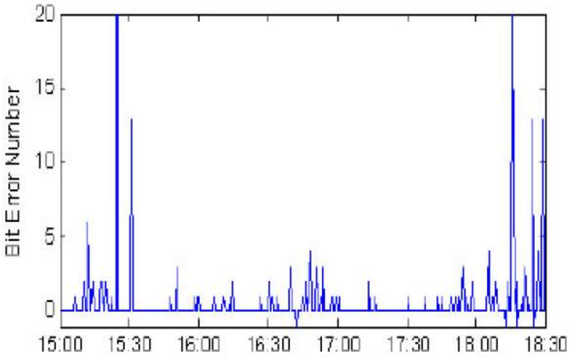
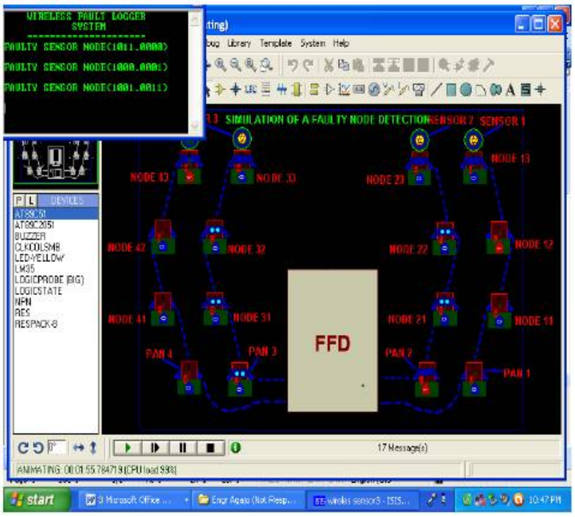


Figure 12 Bit Error Number with time



```
FAULTY SENSOR NODE(1011.0000)
FAULTY SENSOR NODE(1000.0001)
FAULTY SENSOR NODE(1001.0011)
```

```
ANIMATING: 00:01:55.784719 (CPU load 99%)
```

Fig.13 Simulation using PROTEUS LABORATORY showing a Full functional Device(FFD) and Reduce Functional Device(RFD) to realize Artificial Neural Network

III. DISCUSSION OF RESULT

Table I and II shows data collection from a test bed from 3 different Sensors, carbon monoxide and temperature were read at various time of the day these result are taken from the test bed in Auchi Edo State Nigeria ., table III shows how this variable , data transmitted and received where worked out, packet loss and error rate were shown, at different interval data collected were plotted on a graph as shown in the graph in figure 5 and 6 at various time of the day.

Figure 7 is a plot showing comparison between data transmitted and received by a single sensor, with error rate **0.00918** base on equation 12.

Figure8 is a comparison Data rate against number of bits, in figure 9 Packet Delivery ratio was plotted against Packet sent. Error rate with respect to number of packet sent is shown in figure 10, while packet loss against packet sent is shown in figure 11, from the graph can be seen as not been linear, this because the rate in which data is being read is a function of when data is available, thereby making the look the way they are.

The error rate e_r is 0.00918

the final formular becomes

Packet Received = e_r x Packet Transmitted

Packet Received = e_r(Packet Transmitted)

The error estimation model is

$$Error\ rate = \sum_{t=1}^{n} \left(\frac{Error}{n} \right)$$

Figure 12 is a plot of Bit error number with time, error was plotted with respect to time, error generated is not proportionate with weight of data transmitted, percentage error is more with less data.

$$\frac{\delta e(w)}{d\delta wij}$$

w= weight

Figure 13 is a simulation of Artificial Neural Network for a linear model for the system using Proteus simulation software.

figure 14 and 15 are plates showing practical test being carried out, in figure 14 measurement and range is being carried out , while data received id being monitored in figure 15.

Fig 14 field test between FFD and RFD

Fig 15 Indoor monitoring of event

CONCLUSION

The paper came up with a analytic an numeric data transfer scheme which aims measuring data transfer with respect to signal strength and distance, the paper establish an error estimation model for Wireless Sensor Nodes in this regard, the integrity of data received after transmission within a signal coverage range of 45 or less was analysed, Neural Network linear regression method was used to evolve resolve equation that compares error with weight of data received as $\delta e(w)$ against δw_{ij} Packet received, error rate e_r for sensor node was calculated to be 0.00918 thereby establishing the fact that expected packet to be received for every data transmitted is the product of e_r and Packet Transmitted.

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