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VEHICULAR SPEED DETERMINATION USING CELLULAR AND GEO-SPATIAL INFORMATION

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ABSTRACT

The rapid increase in the occurrence of road accidents in Nigeria requires the deployment of real time techniques that is equipped to reduce one of the critical factor that have been identified by the Federal Road Safety cooperation of Nigeria (FRSC) that constitute the major cause of road accidents which is over speeding. This was achieved through the design and implementation of real time vehicle speed monitoring system using cellular signal along the travelled path. A data acquisition device was developed to capture in real time the signal strength and geospatial data (longitude and latitude) along the travel path which is used in determining the speed of the moving vehicle. The acquired data was correlated with data obtained from standardize equipment to establish the integrity of the data, the data was then used to develop the algorithm by obtaining equation for the path-loss gain in terms of signal strength against distance. Equation for the base stations covering a distance of 10km were obtained for analysis. Consequently from the equation, the distance from two locations along the route can be determined from corresponding signal strength values, the average speed results for the drive test, new Model and using Latitude and Longitude are compared as followed 88.05km/hr, 75.67km/hr and 88.2km/hr *respectively. With this a new paradigm shift in vehicular speed management is developed based on Cellular signals for real time vehicular speed determination.*

Keywords: Base station, Cellular, Geospatial data, Signal Strength, Vehicular speed.

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1. INTRODUCTION

Road accidents have become a steady and re-occurring phenomenon in Nigeria which constitutes a menace in modern times. Many factors have been attributed to be the cause the frequent fatal accidents on our roads. These factors include; over-speeding, bad road network, poor driving culture, night trips, over-loading, dangerous driving, poor vehicle maintenance, bad /expired vehicle tires, among others, we worked on over speeding as a major cause of road accident and how we can monitor the speed of vehicles on our roads using cellular and geospatial signals along the travelled path, although both the developed and developing nations of the world have suffered from varying degrees of road accidents, the developing countries clearly dominate with Nigeria having the second highest rate of road accidents among 193 ranked countries of the world (Somuyiwa**,** 2016). Death from reckless driving is the third leading cause of death in Nigeria. (FRSC, 2016) Some factors have been attributed to the frequent fatal accidents on the Nigeria roads. These include; over-speeding, bad road network, poor driving culture, night trips, over-loading, dangerous driving, poor vehicle maintenance, bad /expired vehicle tires, among others. Excess and inappropriate speeds are responsible for a high proportion of the mortality and morbidity that result from road crashes. Over-speeding was estimated to be the main contributory factor to about fifty percent of all crashes. (FRSC, 2014) Excessive speed decreases drivers' response time in an event, and may increase the risk of a crash. It equally reduces the ability to manoeuvre safely on the road, and extends the distance necessary to stop a moving vehicle. This is because, the higher the speed of a vehicle, the longer the time it takes a driver to stop or avoid a crash, which has resulted to loss of lives and properties. If the rate of over-speeding is not checked many more lives and properties would be put to more danger than ever. Though the recent introduction of speed limit by the Federal Road Safety Cooperation is a welcome development but there is still an urgent need to develop a system that can remotely monitor and report in real time vehicular speed on our roads, this is to reduce the pranks by drivers with the Road safety commission along our roads. The objective of this research work is to develop a prototype system that can remotely monitor in real time the speed of a moving vehicle using cellular and geospatial data along the travelled path using the designed system.

2. DESCRIPTION OF STUDY AREA

In this study, Akure-Ilesha Road in Ondo State was used as the case study for primary data collection using the designed data acquisition system. Ilesha-Akure road is one the roads that connects Ondo State and Ekiti state, this also links the old Eastern part of Nigeria to the Western part of Nigeria. Our designed data acquisition system was used to harvest the signal strength along the Akure-Ilesha road; it takes the reading/ value of signal strength, latitude and longitude at intervals of 60 seconds (1 min) for a distance of 27.4km. Fig 1.0 shows the study area of this research work.

Figure 1.0 the Study Area Akure-Ilesha Road.

3. DESIGN OF A DATA ACQUISITION SYSTEM

In actualizing the first objectives of this research work, we designed and implemented a data acquisition system that was used for real time harvesting of the GSM signal strength and latitude and longitude along the selected route. To achieve the above objective, the following device/module was used

1. Gps Module
2. Atmel 328 P-Pu Microcontrolller
3. Sim800 Gsm Module
4. Neo-6 Gps Module
5. Memory Card Module
6. Ardinuo uno App

Fig 1.1 shows the pictorial view of the designed Data Acquisition system,that was used in acquiring data along the travelled path.

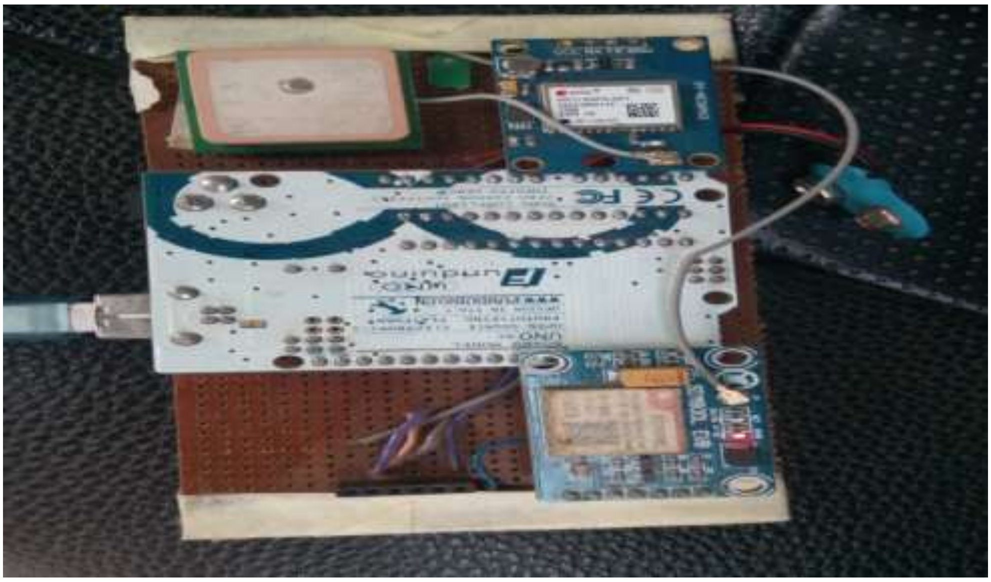

Figure 1.1 Pictorial View of the Designed Data Acquisition System.

3.1. Data Collection Using the Developed Acquisition System

TABLE 1.0 below shows the data collected using the developed data Acquisition system along the travelled path, the data was collected over a distance of 10 km along Akure-Ilesha road in Ondo state Nigeria, the full detail of the data collection can be accessed via Mendeley data repository (Diarah, Reuben 2018)

TABLE 1.0 Data Collection During Drive Test Along Akure-Ilesha Road.

report	sys_date	sys_time	net_op_name	net_op_code	lac_tac	cid	rssi	latitude	longitude
0	2018/7/9	9:15:56	MTN NG	62130	20586	25767	-15	7.39919	5.05944
1	2018/7/9	9:15:58	MTN NG	62130	20586	25767	-15	7.39919	5.05944
2	2018/7/9	9:15:59	MTN NG	62130	20586	25767	-41	7.39919	5.05944
3	2018/7/9	9:16:00	MTN NG	62130	20586	25767	-41	7.39919	5.05944
4	2018/7/9	9:16:01	MTN NG	62130	20586	25767	-41	7.39919	5.05944
5	2018/7/9	9:16:02	MTN NG	62130	20586	25765	-29	7.39919	5.05944
6	2018/7/9	9:16:03	MTN NG	62130	20586	25765	-29	7.39918	5.05943
7	2018/7/9	9:16:04	MTN NG	62130	20586	25765	-29	7.39918	5.05943
8	2018/7/9	9:16:05	MTN NG	62130	20586	25765	-29	7.39918	5.05943
9	2018/7/9	9:16:06	MTN NG	62130	20586	25765	-29	7.39917	5.05943
10	2018/7/9	9:16:07	MTN NG	62130	20586	25765	-29	7.39915	5.05943
11	2018/7/9	9:16:08	MTN NG	62130	20586	25765	-29	7.39915	5.05943

3.2. An algorithm for Vehicular speed based on Cellular Signal Strength.

In developing an Algorithm for Vehicle speed based on cellular signal strength, We plotted the graph of signal strength against distance for each base station and obtained an equation for each base station, such that the distance interval in each base station is determined using the equation and a specific constant (finger printing) is determined for each base station, as can be seen in figures below this constant is used as a multiplying factor for each base station, a correlation between the first and the second base station data, we got a constant K, which we used to multiply base station 2 in order to predict the path-loss between the two base stations.

3.3. EVALUATION OF THE DEVELOPED ALGORITHM.

Drive test was carried out by obtaining different speed along the travelled path at intervals. The signal strength along the road was harvested using the designed data acquisition device, the way the signal strength changes as a function of distance from a radiating source is a function of the environment. The simplest and most exact formulation of this function is applicable in free space.

In other to evaluate the developed Algorithm, the developed data acquisition system captures in real time the signal strength, time, longitude and latitude respectively, thus we verify the developed algorithm by comparing the values of speed from the developed algorithm with the values obtained using geo-spatial information (latitude and longitude).

$$v = \frac{d(m)}{t(s)} \tag{1}$$

Where v is speed of the moving vehicle,

d is the distance covered during the period in question. Measured in metres t is time used to cover the distance. Measured in seconds

The equation of signal strength against distance were obtained for the base stations along the selected route

$$S = \frac{d}{t} \tag{2}$$

$$S = \frac{d_n - d_{n-1}}{t} \tag{3}$$

Where S is speed of the moving vehicle,

Where d_n is the distance covered after time T, Measured in kilometres

t is time used to cover the distance. Measured in seconds.

The distance covered is calculated using the grate circle formula

$$d = ACos(Radians(90 - Lat1))xCos(Radians(90 - Lat2)) + Sin(Radians(90 - Lat1)) \\ xSin(Radians(90 - Lat2))xCos(Radians(Long1 - Long2))xR \tag{4}$$

Where, r =radius =6371(kilometre)

4. RESULTS AND DISCUSSION

From the data collected during the drive test, we plotted the graphs of signal strength against distance.

4.1 GRAPHS FROM DRIVE TEST ALONG AKURE- ILESHA ROAD

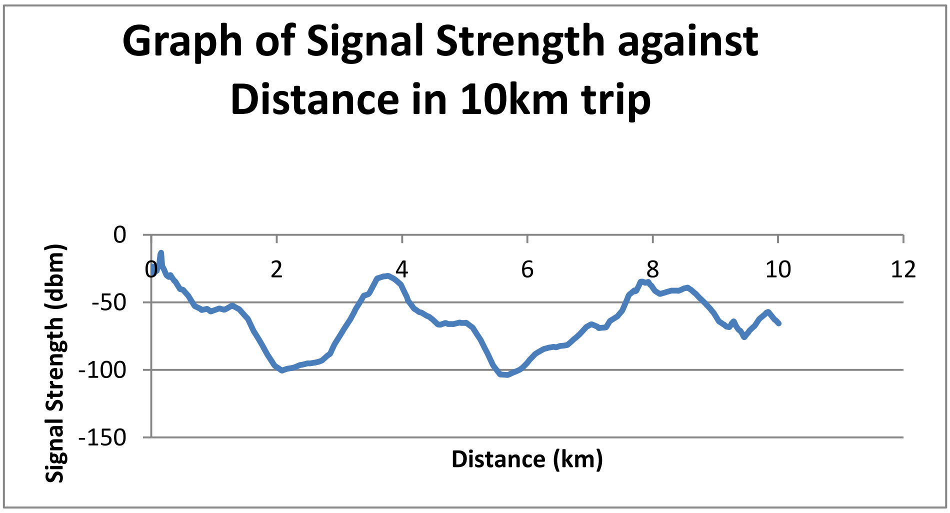

Figure 4.1 Graph of Received Signal strength with over a distance of 10 km

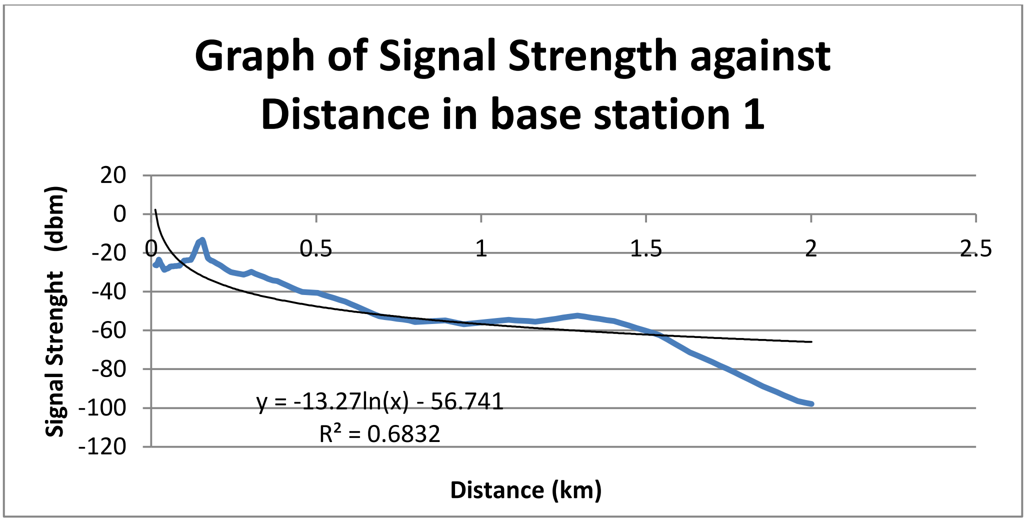

Figure 4.2 graph of signal strength against distance in base station1 of 10km trip.

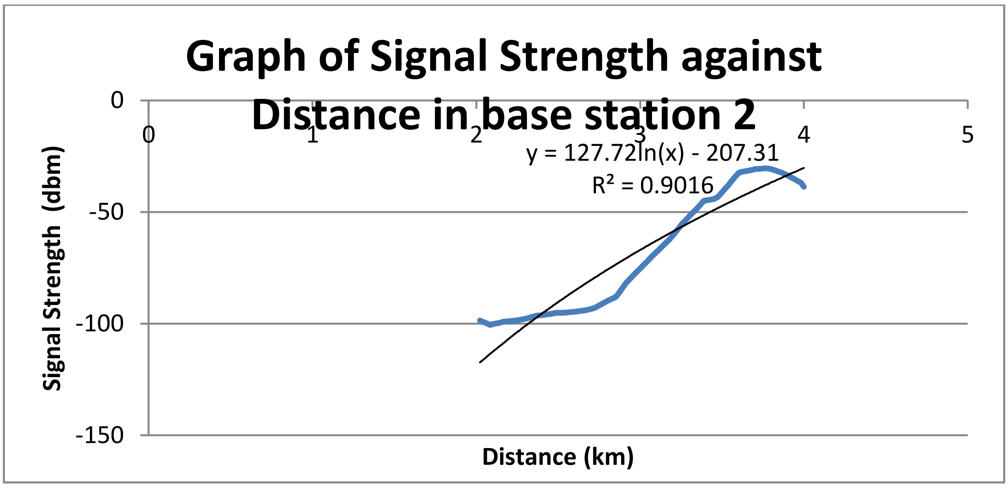

Figure 4.3 graph of signal strength against distance in base station two of 10km trip.

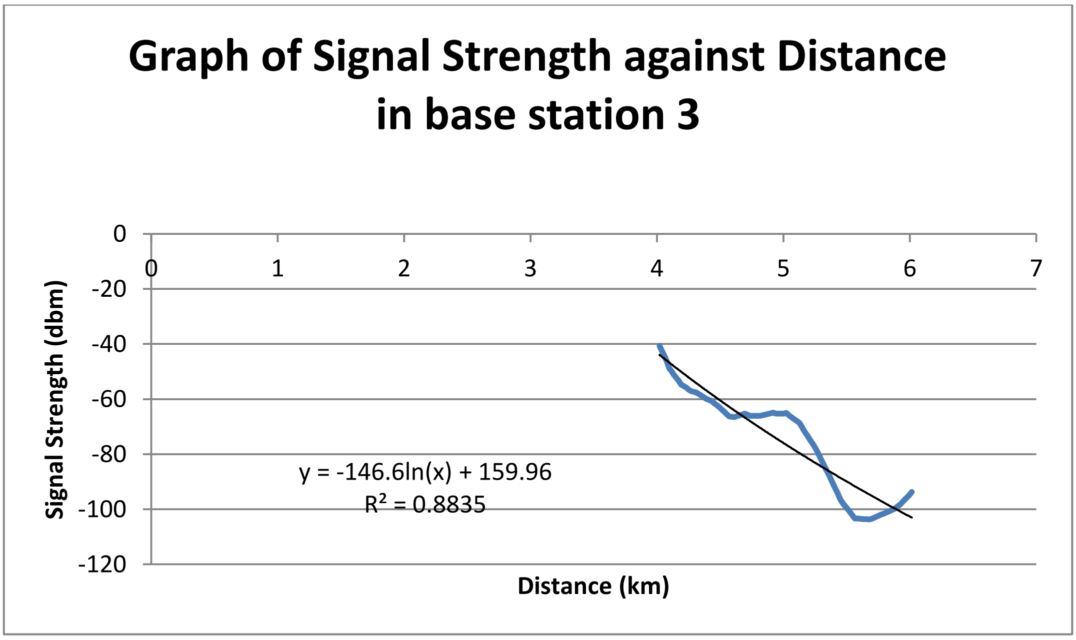

Figure 4.4 graph of signal strength against distance in base station three of 10km trip.

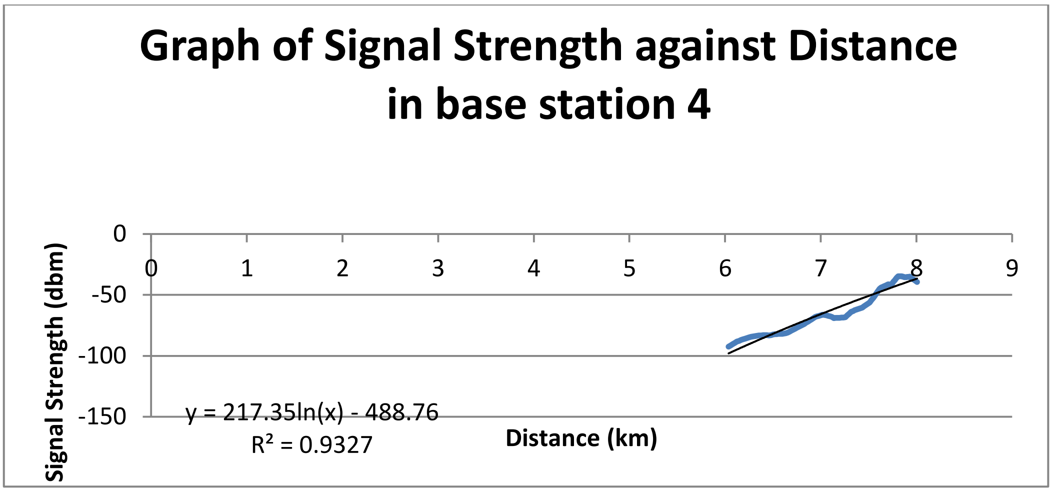

Figure 4.5 graph of signal strength against distance in base station four of 10km trip.

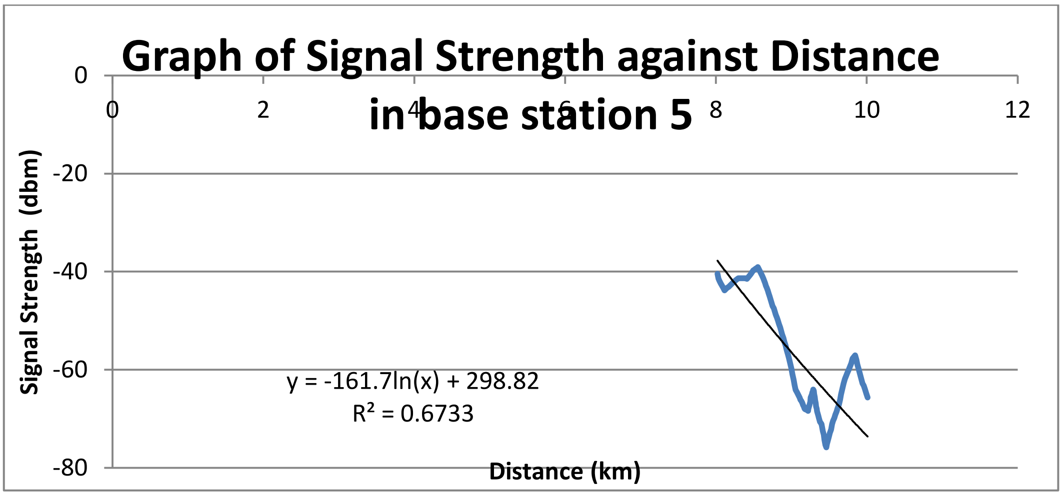

Figure 4.6 graph of signal strength against distance in base station five of 10km trip

From fig 4.1 –fig 4.5 shows the graphs plotted during the drive test along the travelled path.

Fig 4.3, shows a plot of signal strength against distance. From the graph there was an increase in the value of signal strength showing the vehicle was moving towards the base station. The fluctuation in signal strength is as a result of obstruction loss between the transmitter and the receiver (Amir Bashun et al, 2012).

Fig 4.4 shows the graph of signal strength against distance in third base station. From the graph there was a decrease in the value of the signal strength, showing that the vehicle is moving away from the base station.

Fig 4.5 shows the plot of signal strength against distance in base station four, from the graph it was seen that the vehicle was approaching the base station as the value of signal strength increases showing that the vehicle is close to a base station.

Fig 4.6 is a plot of signal strength against distance in base station five: along the 10km trip, from the graph it can be deduced that the vehicle is moving away from the location of the base station as a result of increase in the value of the signal strength from (-30- to -75).the variation of the signal strength is attributed to the topology of the road segment at that particular location. (Amir Bashan et al, 2012).

Also the regression values for fig 4.2-fig 4.6 are (R^2=0.68, 0.90, 0.88, 0.93 and 0.67 respectively), these show that there was good relationship between the signal strength and the distance covered at 5% significance difference.

4.2. Equations deduced from the graph of signal strength against distance

From base station one (1), the equation of the graph is

$$y = -13.27\ln(x) - 56.74(3.4) \quad (5)$$

From base station two (2), the equation of the graph is

$$y = 127.72\ln(x) - 207.31 \quad (6)$$

From base station three (3), the equation of the graph is

$$y = -146.6\ln(x) + 159.96. \quad (7)$$

The distance can be deduced for the

From base station one (1)

$$d\text{=EXP((-S-56.74))} \quad (8)$$

From base station two (2)

$$d\text{=EXP((207.31+S)/127.72)} \quad (9)$$

From base station three (3)

$$d\text{=EXP((159.96-S)/146.6)} \quad (10)$$

TABLE 4.1 Anova: Single factor

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
-15	8	-469	-58.625	451.9821		
-14.4	8	-443.63	-55.4538	359.9237		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	40.22731	1	40.22731	0.099094	0.757563	4.60011
Within Groups	5683.341	14	405.9529			
Total	5723.568	15				

4.3. Validation of the Drive Test Result Using ANOVA

From equation 3.3, $y = -13.27\ln(x) - 56.74$ we used the model equation from the 10km trip to predict the signal strength.

TABLE 4.2: shows the Drive Test signal strength and the predicted signal strength using mathematically model as obtained from the plot of signal strength against distance.

TABLE 4.3: shows the Drive Test to Predict Average Speed.

TABLE 4.2 Drive Test and Predicted Signal Strength

Distance (m)	Drivetest(SS)(dbm)	predicted(SS)(dbm)
0	-15	-14.4
0.25	-30	-34.5591
0.5	-40	-41.4546
0.75	-54	-45.4881
1	-55	-48.35
1.25	-53	-50.5698
1.5	-60	-55.9
1.75	-80	-75.8
2	-97	-91.5

TABLE 4.3 Drive Test to Predict Average Speed.

Time(Min)	Speedav (drive.test) km/h	Speedav (Predicted) km/h
1	40	46.23
2	60	48.498
3	68	44.043
4	40	43.162
5	45	45.855
6	20	32.54
7	60	61.963
8	100	75.378
9	90	92.367
10	110	112.93

Fig 4.7 shows the drive test and predicted signal strength data acquired on 9th July 2018, for signal strength against distance. The high variability of the signal strength was due to the topology of the road the predicted result was obtained from the mathematical expression

derived from mathematical model. The model equation can reproduce the drive test results, without necessarily performing a drive test.

One-way analysis of variance (ANOVA) was carried out at 5% significance level to evaluate significance difference between the experimental and predicted data, throughout the period of this test. It can be deduced that there was no significant difference observed between the experimental and predicted results as $p > 0.05$. This means that the mathematically model was able to predict and reproduce the experimental data thereby making the model responsive.

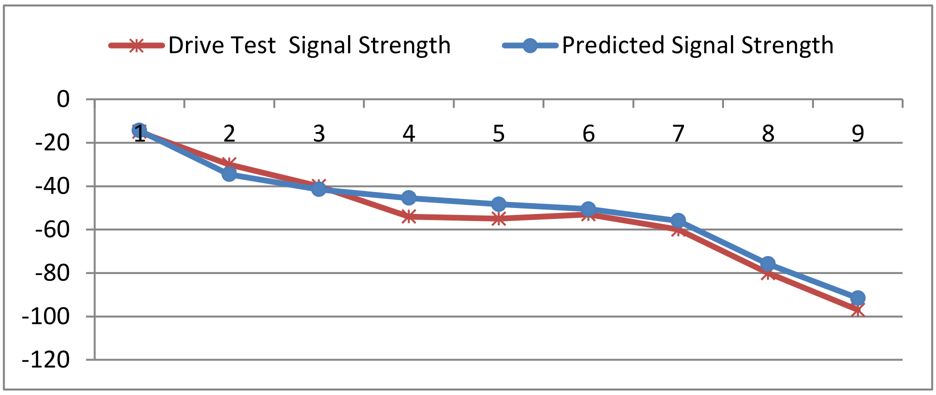

Figure 4.7 Drive Test and predicted signal strength on 9th July, 2018.

5. CONCLUSION

Nigeria has witnessed series of accident on its road as a result of many factors which includes: over speeding of the driver, drunk driving, bad roads, bad tires. the rate of accident on Nigeria roads which have witness several types of accidents have caused more harm than good, this is as result of over-speeding of drivers on Nigeria roads, however this will be drastically reduced if there is real time vehicle speed monitoring of all vehicle on Nigeria roads, this will help in reducing the rate of road accidents due to over-speed. This research made use of signals from base stations along Akure-Ilesha road in determining the speed of moving vehicle using the GSM signal strength received by our designed data acquisition system along the travelled path.

We developed a data acquisition system that was able to capture the GSM signal strength along travelled path, these signal strengths were used in determining the position of the vehicle at every point using the base stations along the travelled path which has its own specific local area code (LAC) and cell identification code (CID) that identifies geographical location of every base in Nigeria, these signal strengths were used in determining the speed of the vehicle as it travels along the route, which helps in real time speed determination of vehicles in reducing the rate of accident on Nigeria roads, with this development, a new paradigm shift in vehicular speed management is developed based on GSM signals for real time speed determinant.

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