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Prediction of Vertical Handover Using Multivariate Regression Model

Siddharth Goutam, Srija Unnikrishnan, Sundary Prabavathy, Neel Kudu

Abstract : ***Choosing the best performing network among the pool of available networks is a challenge faced by every mobile user. This paper majorly focuses on the development of a system that can ease the above task based on available parameters like Received Signal Strength, Bandwidth, Cost, Network Coverage, Jitter, Packet Loss, Latency etc. The system uses Multivariate Regression Model to help select the best network with the help of a mobile application. The algorithm assigns a Handover value to each available network among the pool of available networks and makes a comparative study to facilitate the decision of the best performing network. The system can also be used by service providers to optimise their network performance by studying the effect of change in the network parameters. Another possible application can be to check the Handover feasibility of future technology networks. The paper also tries to focus on the giving insights on the influence each network parameter mentioned above has on the final value of Handover by using statistical methods and ANOVA.***

Keywords: Vertical Handover (VHO), Handover Value (HV), Received Signal Strength (RSS), Quality Of Service (QoS) Analysis Of Variance (ANOVA), Multivariate Linear Regression (MLR), Coefficient Of Correlation, Coefficient Of Regression

I. INTRODUCTION

In the last few years, there has been a significant increase in data usage in the wireless networks. The increase in the data usage is mainly attributed to the increased use of various mobile applications across all verticals [1].Seamless uninterrupted connectivity at anytime, anywhere and on any device has become the norm. This is practically possible only when efficient vertical handover algorithms are implemented, prioritizing user interests, as he moves across networks [2]. The mobile user needs to be connected to the best network among the different options available at that particular time in his vicinity [3].Vertical Handover Decision Algorithms (VHDAs) decide on the network to which the handover is to be performed from among the multiple available networks, based on the comparison of a set of parameters. Received Signal Strength (RSS), Bandwidth, Cost, Battery Status, Security, User Preferences and Quality of Services are some of the main parameters, generally considered, as indicated in Fig 1. All these parameters effectively impact the final decision [4]. Quality of Service (QoS) is given as function of latency, jitter and packet loss in the network.

$QoS = f(latency, jitter, packet\ loss\ in\ the\ network)$ [3].

In this paper, we have calculated the handover value on the basis of RSS, Bandwidth, QoS and Network coverage.

$Handover\ Value = f(RSS, Bandwidth, QOS, Network\ Coverage)$

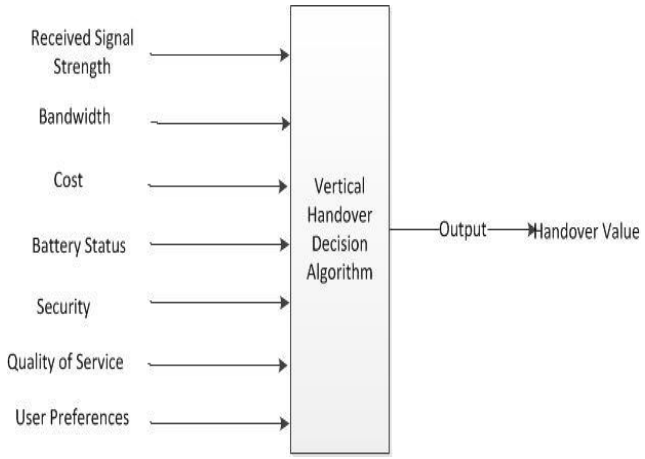

Figure 1 Parameters for Vertical Handover

The relationship between the variables is very much logical and can be established by using the statistical methods like regression and correlation analysis [5].Analysis of Variance (ANOVA) test is performed for examining the change or difference between the means of two or many sets of observations [6]. The relationship between the variables is established through correlation analysis. The same needs to be corroborated with proper hypothesis [7]. In this research paper, we have presented the correlation and regression analysis between the parameters influencing the handover decision. Also the prediction of the QoS and handover value is done using the multivariate regression model.

II.STATISTICAL METHODS & CONCEPTS

2.1 Regression Analysis

Regression Analysis is used to predict the best estimate of the response based on the knowledge of the predictor. In Regression Analysis we have two types of variables.

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X_i - the predictor or independent variable or regressor
Y_i - the response or the dependent variable or regressed variable.
$\bar{X}$ *and* $\bar{Y}$ denotes the respective means
There are two methods for the regression analysis Least Square Method and Normal Regression Method

Under Method of Least Squares

$$S_{XY} = \sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y}) \quad (1)$$

$$\beta = \frac{S_{XY}}{S_{XX}} \quad (2)$$

$$Y_i = \propto + \beta X_i \quad (3)$$

$$\alpha = \bar{Y} - \frac{S_{XY}}{S_{XX}}\bar{X} \quad (4)$$

$$S_{XX} = \sum_{i=1}^{n}(X_i - \bar{X})^2 \quad (5)$$

The linear equation obtained from (3) is called the line of best fit for the given data.

The coefficient of correlation is given by

$$r_{XY} = \frac{\sum_{i=1}^{n}(X_i-\bar{X})(Y_i-\bar{Y})}{\sqrt{\sum_{i=1}^{n}((X_i-\bar{X})^2)}\sqrt{\sum_{i=1}^{n}((Y_i-\bar{Y})^2)}} \quad (6)$$

2.2 Analysis of Variance (ANOVA)

Analysis of Variance (ANOVA) is used for testing the significant difference in a specified factor due to different aspects (independent variable) at different levels of significance [8].

In this paper ANOVA is used for

a. testing the significant difference in QoS due to change in latency, jitter and packet loss.
b. testing the significant difference in handover value due to the change in RSS, Bandwidth and QoS.

2.3 Multivariate Regression Analysis

Multivariate Regression Analysis can be expressed by using the following equation

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots \beta_m X_m + \beta_n X_n + \epsilon \quad (7)$$

Where Y = dependent variable
X_i represents independent variable
β_i denotes weighting coefficients
ϵ denotes error [9]

III. DESIGN AND IMPLEMENTATION

The Vertical Handover Decision Algorithm (VHDA) designed and implemented, is based on fuzzy logic. The Fuzzy Inference System is constructed based on RSS, bandwidth, network coverage, Quality of Service (Fig 2). This system used for the generation of dataset required for Multivariate Regression Analysis [3].
Ping-Pong effect, which is defined as unnecessary handovers between the networks due to the fluctuations in RSS, is avoided here. This is ensured by executing the handover, only if the difference between the handover value of the networks involved is greater than a fixed threshold value.

As shown in Fig 2, there are two Fuzzy Inference Systems FIS 1 and FIS 2. The handover value is the final output of Fuzzy Inference System 2 (FIS 2).

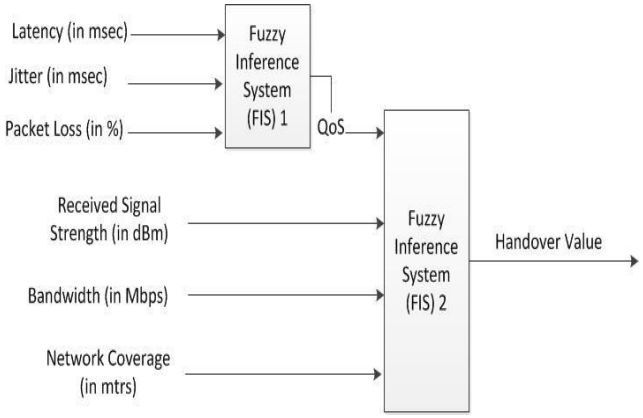

Figure 2 System Model for Fuzzy Inference System

Table I captures the details of the universe of discourse for all parameters in FIS.

Table I Universe Of Discourse For Parameters Of FIS: Minimum And Maximum Values

Parameter	Minimum Value	Maximum Value
RSS (in dBm)	-78	-66
Bandwidth (in Mbps)	1	14
Network Coverage (in mts)	1	150
Quality Of Service (QoS)	0	7
Latency (in msec)	0	6
Jitter (in msec)	0	6
Packet Loss (in %)	0	6

For simulation, we have considered the following Multivariate Linear Regression Equation for QoS

$$QoS = \beta_0 + (\beta_1 * L) + (\beta_2 * J) + (\beta_3 * PL) \quad (8)$$

Where
QoS denotes Quality of Service
L denotes Latency
J denotes Jitter
PL denotes Packet Loss
$\beta_0, \beta_1, \beta_2, \beta_3$ denotes coefficient of Multivariate Regression Model
Multivariate linear regression equation for Handover is expressed as under

$$HV = \gamma_0 + (\gamma_1 * RSS) + (\gamma_2 * B) + (\gamma_3 * NC) + (\gamma_4 * QoS) \quad (9)$$

Where
HV denotes Handover Value
RSS denotes Received Signal Strength
B denotes Bandwidth
NC denotes Network Coverage
QoS denotes Quality of Service
$\gamma_0, \gamma_1, \gamma_2, \gamma_3$ are the coefficients of the Multivariate Regression Model

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IV. SIMULATION & RESULTS

4.1 Simulation

The flowchart for Vertical Handover using Multivariate Regression Model is shown in Fig 3 and Fig 4 captures the algorithm. The simulation has been done for the flowchart on Python. The statistical analysis has been done on the dataset generated for 4G and Wi-Fi networks. The measurement of the network parameters has been done based on the respective mobile applications. Figures 5 and 6 provide sample screenshots.

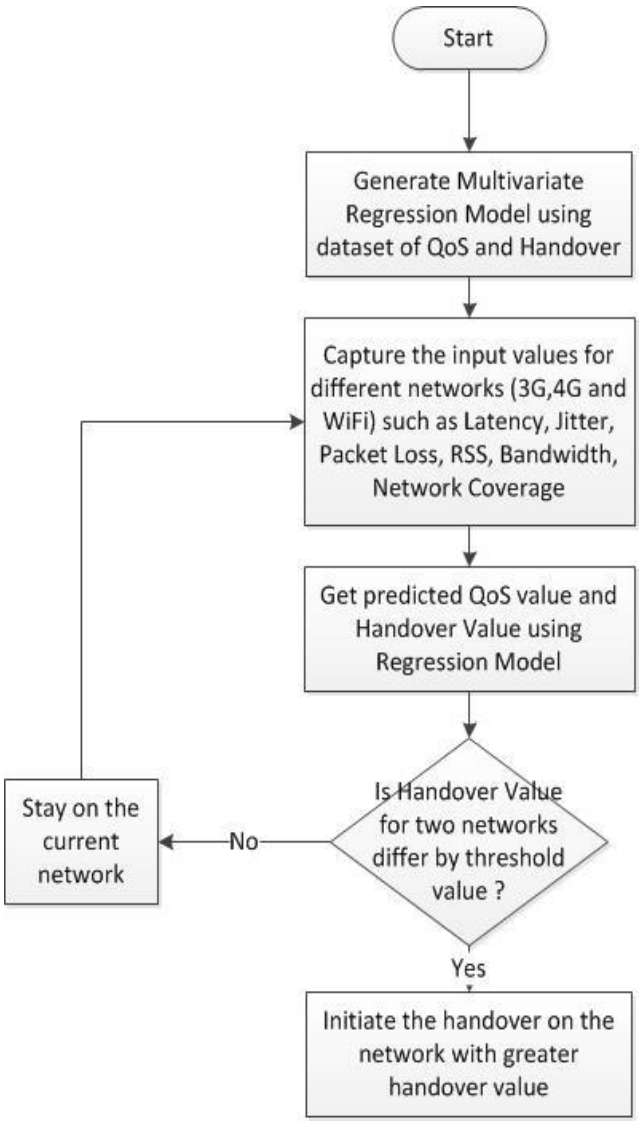

Figure 3 Flowchart for Vertical Handover using Multivariate Regression Model

Algorithm for Vertical Handover using Multivariate Model

Inputs – Latency, Jitter, Packet Loss, RSS, Bandwidth, Network Coverage ,
Dataset

Output – Value of QoS & Handover

Steps to be followed –

1. Function Multivariate_Linear_Regression ( )
2. Define:
   X : Independent variables (Latency, Jitter, Packet Loss, RSS, Bandwidth, Network Coverage)
   Y : Dependent variables (QoS, Handover)
3. Train Test split:
   Split dataset into train and train dataset
4. Define Linear Regression Model
5. Run the Model for QoS and get the coefficients for the independent factors
6. $QoS = \beta_0 + (\beta_1 * L) + (\beta_2 * J) + (\beta_3 * PL)$
7. Run the Model for Handover and get the coefficients
8. $HV = \gamma_0 + (\gamma_1 * RSS) + (\gamma_2 * B) + (\gamma_3 * NC) + (\gamma_4 * QoS)$
9. Return the Handover Value of the Network
10. Function main( )
    {
11. Run the application to get all the required network parameters of all available networks in vicinity
12. For i = 1 to n
    n – number of available networks in the vicinity
13. Create the list of all the required network parameters
14. $Network_i$ = ($Latency_i$, $Jitter_i$, Packet $Loss_i$, RSS_i, $Bandwidth_i$, NC_i)
15. Call Multivariate_Linear_Regression ( ) & pass the above list of parameters
16. For Networki get the QoS_i and Handover $_i$
    }
17. Repeat above steps for all the available n networks
18. Compare all the Handover values
19. Get the maximum value of QoS & Handover
20. Handover to the same network
    End

Figure 4 Algorithm for Vertical Handover using Multivariate Regression

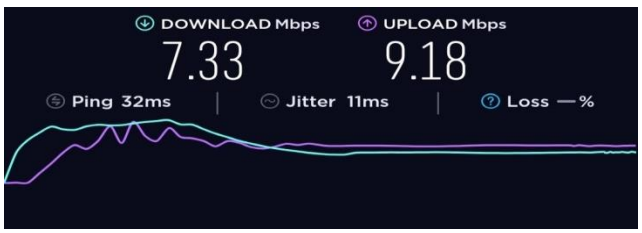

Figure 5 Measurement of Parameters for 4G Network

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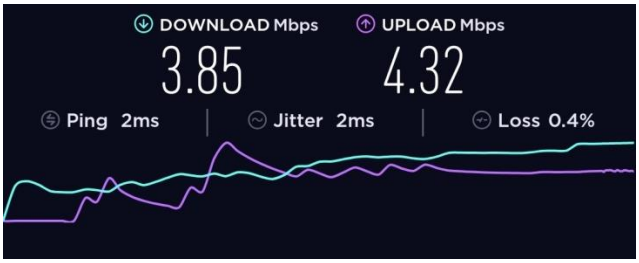

Figure 6 Measurement of Parameters for WiFi Network

Table II captures the simulation parameters.

Table II Simulation Parameters

S. No	Simulation Parameter	Value	
		4G Network	WiFi
1	Latency	32	2
2	Jitter	11	2
3	Packet Loss	0	0.4
4	RSS	-84	-78
5	Bandwidth	7.33	3.85
6	Network Coverage	150	150

The dataset has been created based on the measurements done above. The analysis of the data has been done based on the statistical methods and concepts captured in section II i.e. Fig 2 and Table I.

4.2 Simulation Results

Intercept:
6.52823109609
Coefficients:
[-0.16980346 -0.16980346 -0.16980346]
QoS = β_0 + β_1 * Latency + β_2 * Packet Loss + β_3 * Jitter
β_0 = 6.52823109609
β_1 = -0.169803455121
β_2 = -0.169803455121
β_3 = -0.169803455121
Intercept:
3.27447523366
Coefficients:
[0.02589576 0.02336095 0.01994294 0.00181286]
Handover Value = γ_0 + γ_1 * QOS + γ_2 * RSS + γ_3 * Bandwidth + γ4 * Network coverage
γ_0 = 3.27447523366
γ_1 = 0.0258957590337
γ_2 = 0.0233609547633
γ_3 = 0.0199429399712
γ_4 = 0.00181285557923

Enter the Latency value for Current Network 32

Enter the Packet Loss for value Current Network 0

Enter the Jitter value for Current Network 11

Enter the RSS value for Current Network -84

Enter the Bandwidth value for Current Network 7.33

Enter the Network Coverage value for Network 150

Enter the Latency value for Available Network 2

Enter the Packet Loss for value Available Network 0.4

Enter the Jitter value for Available Network 2

Enter the RSS value for Available Network -78

Enter the Bandwidth value for Available Network 3.85

Enter the Network Coverage value for Available Network 150

Predicted QoS value for Current Network
[-0.77331747]
Predicted Handover value for Current Network
[1.71023948]

Predicted QoS value for Available Network [5.78109589]
Predicted Handover value for Available Network
[1.95073528]
Handover on Available network

It can be observed that even with some input values lying outside the universe of the discourse, as mentioned in Table I, the Multivariate Regression Model gives reliable handover decision, taking all parameters into account.

4.3 Multivariate Regression Model for QOS

Intercept (β_0):
6.52823109609
Coefficients ($\beta_1, \beta_2, \beta_3$) :
[-0.16980346 -0.16980346 -0.16980346]

$$QoS = 6.5282 - (0.1698 * \text{Latency}) - (0.1698 * \text{Packet Loss}) - (0.1698 * \text{Jitter})$$

Table III & IV captures Model summary and Regression statistics for QoS

Table III Model Summary for QoS

Method	Least Square
No of Observations	343
Degrees of Freedom of Residuals	339
R-Squared	0.835
Adj. R Squared	0.834
F-Statistic	573.0

Table IV Regression Statistics for QoS

	Coef	Std err	t	p>|t|	0.025	0.975
const	6.5282	0.039	165.286	0.00	6.451	6.606
Latency	-0.1698	0.007	-23.937	0.00	-0.184	-0.156
Packet Loss	-0.1698	0.007	-23.937	0.00	-0.184	-0.156
Jitter	-0.1698	0.007	-23.937	0.00	-0.184	-0.156

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4.4 Multivariate Regression Model for Handover

Intercept:
3.27447523366 (γ_0)
Coefficients ($\gamma_1, \gamma_2, \gamma_3, \gamma_4$):
[0.02589576 0.02336095 0.01994294 0.00181286]
Handover Value = 3.2745 + (0.0259 *QoS) + (0.0234*RSS) + (0.0199*Bandwidth) + (0.0018* Network Coverage)
Table V & VI captures Model Summary and Regression Statistics for Handover Value.

Table V: Model Summary for Handover Value

Method	Least Square
No of Observations	222897
Degrees of Freedom of Residuals	222892
R-Squared	0.781
Adj. R Squared	0.781
F-Statistic	1.992e+05
Covariance Type	Non robust

Table VI: Regression Statistics for Handover Value

	Coef	Std err	t	p>|t|	0.025	0.975
const	3.2745	0.003	982.36	0.000	3.268	3.281
QoS	0.0259	7.4e-05	350.04	0.000	0.026	0.026
RSS	0.0234	4.5e-05	510.55	0.000	0.023	0.023
Bandwidth	0.0199	4.2e-05	465.94	0.000	0.020	0.020
Network Coverage	0.0018	3.9e-06	457.90	0.000	0.002	0.002

The terms used in the above tables are as follows:
R-squared: R-squared is a statistical measure of how close the data are to the fitted regression line.
Adj R-squared: It decreases when a predictor improves the model by less than expected by chance. The adjusted R-squared can be negative, but it's usually not. It is always lower than the R-squared.
p-value: The p-value for each term tests the null hypothesis that the coefficient is equal to zero (no effect). A low p-value (< 0.05) indicates that the null hypothesis can be rejected. In other words, a predictor that has a low p-value is likely to be a meaningful addition to the model because changes in the predictor's value are related to changes in the response variable.
t-value: The t-value measures the size of the difference relative to the variation in sample data. Putting this in another way, T is simply the calculated difference represented in units of standard error. The greater the magnitude of T, the greater the evidence against the null hypothesis.
Std error: standard error of the estimate, represents the average distance that the observed values fall from the regression line.

4.5 Inference from Multivariate Regression Analysis

Tables (Table III, IV, V and VI) –

1. From the above tables (Table IV and Table VI) we have observed that the p-value is 0.000. This clearly indicates that the model which is estimated by the regression procedure is significant at an α-level of 0.05. Thus at-least one of the regression coefficients is different from zero.
2. The R-Squared: R^2 is also known as the coefficient of the multiple determination. It is useful criteria for measuring the goodness of the fit of the multiple regression model.
   From table III, R^2 value is 83.5% indicates that 83.5% of the total variation of the Y values about their mean can be explained by predictor variables used in this model.
3. The adjusted R. Squared value (R_a^2) indicates that 83.4% of the total variation of Y values about their mean can be explained by predictor variables in the model.
4. We also observed that R^2 and R_a^2 are very close. This clearly implies that at-least one of the predictor values contributes information for the prediction of Y.
5. Thus both the values indicate that the model fits the data well.
6. We have similar observation of R^2 (78.1%) and R_a^2 (78.1%) from table V, which clearly indicates that model fits the data well.

V. STATISTICAL ANALYSIS

5.1 ANALYSIS FOR QUALITY OF SERVICE (QoS)

5.1.1 Linear Regression Analysis

Scenario 1: Latency (L) as independent variable (X) and QoS as dependent variable (Y) (Putting Jitter and Packet Loss as constant)
Table VII captures the Dataset values of QoS with variation in Latency.

Table VII Latency Vs QoS

Latency	QoS
0	6.334512231
1	6.113636364
……	…….
……..	…….
6	4.768035259

Basis the calculations, the required line of best fit to the above data is
Y = -0.2569 X + 6.3607 (10a)
QoS = -0.2569*Latency + 6.3607 (10b)
Inference: QoS changes by -0.2569 units with unit increase in Latency.
The curve of QoS (dependent variable – Y) vs Latency (independent variable X) is shown in Figure 7. (Latency is on X axis. QoS is on Y axis.)

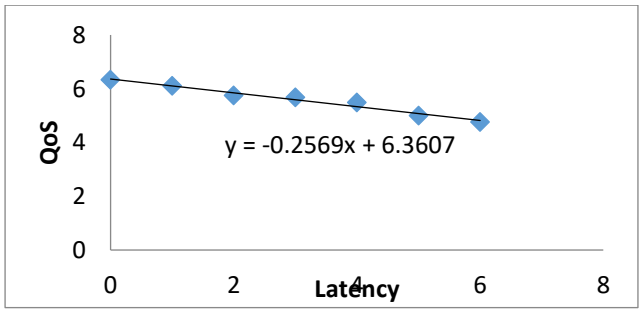

Figure 7 QoS Vs Latency

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From the dataset, we have obtained the line of best fit for QoS as follows (in equation 11b & 12b)

Y = - 0.4453 X + 5.2873 (11a)

QoS = - 0.4453* Jitter + 5.2873 (11b)

Inference: QoS changes by -0.4453 units with unit increase in Jitter.

Y = -0.2963X + 5.8889 (12a)

QoS = -0.2963*Packet Loss + 5.8889 (12b)

Inference: QoS changes by -0.2963 units with unit increase in Packet Loss.

5.1.2 Correlation Analysis

Table VIII gives the correlation between QoS and the main parameters of influence, using equation 6.

Table VIII Correlation Analysis

Co-relation Between QoS as dependent variable	Value
Independent variable = Latency	r = -0.986 (negative)
Independent variable = Jitter	r = -0.873 (negative)
Independent variable = Packet Loss	r = - 0.995(negative)

Inference –

From the above table, we infer that Latency, Jitter, Packet Loss and QoS are highly negatively correlated i.e. if Latency, Jitter and Packet Loss increase we can expect QoS value to decrease.

5.1.3 ANOVA (Two-way) for QoS (Latency & Packet Loss with Jitter as Constant)

H_0 = There is no significant change in average QoS values due to different values of Latency and Packet Loss (with Jitter as constant).

H_1 = There is significant change in average handover values due to different values of Latency and Packet Loss (with Jitter as constant).

Table IX shows the values of QoS corresponding to different values of Latency and Packet Loss. Packet Loss varies from 0 to 6 % (in columns) while Latency is varying from 0 to 6 msecs (in rows). Jitter is taken constant at 6msecs.

Table IX QoS Values for Packet Loss and Latency

Packet Loss / Latency	0	1	……..	6
0	5	5	……..	5
1	5	4.768035	……	4.768035
…..	…..	…..	…..	…..
…..	…..	…..	…..	…..
…..	…..	…..	…..	…..
…..	…..	…..	…..	3.665487
6	5	4.768035		1.66666

Analysis of Variance (ANOVA)

Number of Rows (r): 7

Number Of Columns (c): 7

Total Number of entries (n): 49

T: 218.99126

Correction factor: 978.7178

Table X is the ANOVA table.

Table X ANOVA Table

	Sum of Squares		Degrees of Freedom		Mean Square
SSC	5.23172	c-1	6	MSC	0.87195
SSR	5.23173	r-1	6	MSR	0.871955
SSE	5.8133	(n-1)-(c-1)-(r-1)	36	MSE	0.1614
SST	16.276	n-1	48	MST	0.3391

SSC – Sum of Squares for Columns

SSR – Sum of Squares for Rows

SSE – Sum of Squares due to Error

SST - Total of Sum of Squares

The ratios calculated as per the ANOVA are as under –

$F_{PACKET\ LOSS}$ = MSC /MSE

$F_{PACKET\ LOSS}$ = 5.399

$F_{LATENCY}$ = MSR / MSE

$F_{LATENCY}$ = 5.399

Referring to the Standard Table – 95th Percentile Values (0.05 Levels) $F_{0.95}$ for F Distribution, we have

$F_{PACKET\ LOSS}$ (6, 36) = 2.34

$F_{LATENCY}$ (6, 36) = 2.34

Since TV < CV; Reject H_0

Accept H_1.

TV: Table Value

CV: Calculated Value

On the similar lines, ANOVA (Two Way) for QoS (Jitter & Packet Loss with Latency as Constant) and QoS (Jitter & Latency with Packet Loss as constant) is calculated.

In both cases, Hypothesis H_1 stands accepted.

5.2 ANALYSIS FOR HANDOVER VALUE

5.2.1 Linear Regression Analysis

Scenario 1 - Received Signal Strength (RSS) as independent variable (X) and Handover Value (HV) as dependent variable (Y) (Putting bandwidth and QoS as constant)

Table XI captures the values of handover value with variation in RSS.

Table XI RSS Vs Handover Value

RSS	Handover value
-78	2
-77	2.019783084
……	……
…….	……..
-66	2.382262997

From the dataset, we have obtained the line of best fit for Handover Value (HV) as follows

Y = 0.0346 X + 4.7504 (13a)

HV = 0.0346*RSS + 4.7504 (13b)

Inference: Handover Value increases by 0.0346 units with unit increase in RSS.

The curve of Handover Value (dependent variable Y) vs RSS (independent variable X) is shown in Figure 8. (RSS is on X axis. Handover Value is on Y axis.)

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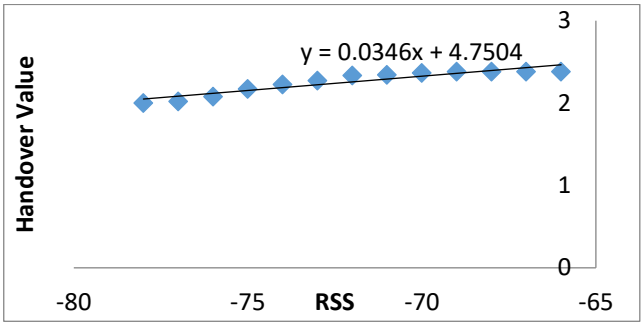

Figure 8 Handover Value Vs RSS

From the dataset, we have obtained the line of best fit for Handover Value as follows (in equation 14b & 15b)

Y = 0.0584 X + 2.0071 (14a)
HV = 0.0584*QoS + 2.0071 (14b)

Inference: Handover Value increases by 0.0584 units with unit increase in QoS.

Y = 0.0283 X + 2.0632 (15a)
HV = 0.0283*Bandwidth + 2.0632 (15b)

Inference : Handover Value increases by 0.0283 units by unit increase in Bandwidth.

5.2.2 Correlation Analysis

Table XII gives the correlation between the handover value and the main parameters of influence.

Table XII Correlation Analysis

Co-relation Between Handover Value as dependent variable	Value
Independent variable = RSS	r = 0.933 (positive)
Independent variable = QoS	r =0.983 (positive)
Independent variable = Bandwidth	r = 0.918(positive)

Inference -

From the above table, we infer that RSS, QoS, Bandwidth and Handover Value are highly positively correlated i.e. if RSS, QoS and Bandwidth increases we can expect the handover value to increase.

5.2.3 ANOVA (Two-way) for Handover Value (RSS & QoS with Bandwidth & Network Coverage as constant)

H_0 = There is no significant change in average handover values due to different values of RSS and QoS.

H_1 = There is significant change in average handover values due to different values of RSS and QoS.

Table XIII shows the values of handover corresponding to different values of RSS and QoS. QoS varies from 0 to 7 (in columns) while RSS is varying from -78 to -66 dbm (in rows). Bandwidth & Network Coverage are taken constant at 14 Mbps & 150 mts respectively.

Table XIII Handover Values for RSS and QoS

QoS / RSS	0	1	……..	7
-78	2	2	……..	2
-77	2	2.024	……	2.019
…	……	……..	……..	……
….	……	……..	……	……
			……..	
-67	2	2.0345	……	2.38226
-66	2	2.0345	…….	2.382263

Analysis of Variance (ANOVA)

Number of Rows (r): 13
Number of Columns (c): 8
Total Number of Entries (n): 104
T: 223.7311
Correction factor: 481.3041
Table XIV is the ANOVA table.

Table XIV ANOVA Table

	Sum of Squares		Degrees of Freedom		Mean Square
SSC	0.907941	c-1	7	MSC	0.1297
SSR	0.57746	r-1	12	MSR	0.04812
SSE	0.308874	(n-1)-(c-1)-(r-1)	84	MSE	0.003677
SST	1.79428	n-1	103	MST	0.01742

The ratios calculated as per the ANOVA are as under –

F_{QoS} = MSC /MSE
F_{QOS} = 35.274
F_{RSS} = MSR / MSE
F_{RSS} = 13.0871

Referring to the Standard Table – 95th Percentile Values (0.05 Levels) $F_{0.95}$ for F Distribution, we have

F_{QOS} (7, 84) = 2.09
F_{RSS} (12, 84) = 1.83

Since TV < CV; Reject H_0
Accept H_1.
TV: Table Value
CV: Calculated Value

On the similar lines, ANOVA (Two Way) for Handover Value (RSS & Bandwidth with QoS and Network Coverage as constant) and Handover Value (Bandwidth & QoS with RSS and Network Coverage as Constant) is calculated.

In both cases, Hypothesis H_1 stands accepted..

VI.CONCLUSION

Here we have developed a Vertical Handover Decision Algorithm based on Multivariate Regression, considering RSS, Bandwidth, QoS and Network Coverage. The system can make fast decisions, without any overhead to the user. Since the model uses the most crucial and measurable parameters for decision making, it can be considered accurate and reliable. Also the statistical analysis presented illustrates the inter-dependency of the different parameters in determining QoS and handover value. The results can help service providers assess the effect of each network parameter on the network performance. The system can also help in optimizing the design and deployment locations of Mobile stations to give better user experience. Use of Multivariate Algorithm makes the system robust independent of the Network technologies.

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