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A New Vertical Handover Prediction Method for Heterogeneous Wireless Networks

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Abstract: Long Term Evolution (LTE) is the fourth generation (4G) cellular network technology that provides improved performance that related to data rate, coverage and capacity compared to earlier cellular systems. The addition of many small cells in a heterogeneous network configuration provides a means to enhance capacity through extreme frequency reuse. The heterogeneous environment of different network technologies can provide high data rate and enhance multimedia services, but it is challenging to provide optimized handover (HO). In this paper, a new method is proposed to select the optimal network from available networks to which a UE may be handed over to achieve better QoS performance. The aggregation of multiple criteria for calculation of overall ranking of networks is obtained by Analytical Hierarchy Process (AHP) [1] and is combined with the history of previously visited cells and regression analysis of the Layer 1 (L1) and Layer 3 (L3) filtered Received Signal Strength (RSS) data for prediction of future values. The AHP is used to calculate the weights for the system attributes and to rank the available networks based on multiple criteria Multiple Attribute Decision Making (MADM). The sequence of visited cells is used in target network selection as it reduces frequent handover. The sequence of visited cells would be modeled as a Markov Chain. To assess RSS, beside L1, L3 filtering RSS prediction and smoothing is used to predict future signal samples to hasten the process of HO. RSS forecasting is used to predict handover necessity so as to reduce the handover delay. The results show that the number of handovers is reduced by up to 50% compared to the conventional AHP. The results also show that the threshold crossing rate and average duration of fades are reduced by 47% compared with the AHP. Handover delay is also reduced by up to 40 ms due to RSS forecasting.

***Key word**: Vertical handover, 4G, RSS regression and forecasting, threshold crossing rate and average duration of fade.*

1. INTRODUCTION

Since its inception, cellular mobile communication technology witnessed great advances and innovations. Many generations of the technology were developed, each newer generation having better features than the earlier ones and better capabilities, economics and availability of the network, devices and service offerings LTE networks are providing speeds approaching 100 Mbps, but these are only possible under ideal conditions on lightly loaded networks and where user equipment is close to the base station (BS) radio antenna.

In mobile communication, User Equipment (UE) always demands to be on the network and to perform different errands using applications like file transfer, video streaming and conferencing and other applications like messaging, *etc*. With the increasing deployment of a variety of wireless access networks, wireless devices face the challenge of selecting the most suitable network from a set of available access networks.

The heterogeneous networks of Wi-Fi, LTE and Wimax networks can provide high data rate and enhanced multimedia services, but its challenge is to provide optimized handover. Vertical handover (VH) algorithms are very important components of forth generation (4G) network architecture. These algorithms need to be designed to Provide the required Quality of Services (QoS) to a wide range of applications while allowing seamless roaming among a multitude of Access network technologies. Like other cellular mobile radio systems, one of the main performance requirements in LTE network Is to provide fast and seamless handover from one cell to another to meet a strict delay requirement while simultaneously keeping network management simple. Hence, the decision of handover necessity and proper handover execution are crucial component in the design process of handover.

The objective of this framework is to provide an optimized handover decision which minimizes unnecessary handovers and handover failures using the handover necessity estimation unit and using the history of visited cell concepts. A another objective is to reduce signaling overhead in the networks caused by scanning large number of cells and increases the users' satisfaction by improving the QoS.

2. BACKGROUND AND RELATED WORKS

In the 4G wireless environment, a mobile user is able to continue using the mobile device while moving from one point of attachment to another. Such process is called a handover, by which a mobile terminal keeps its connection active when it migrates from the coverage of one network access point to another. Handover is the process of maintaining a user's active sessions when a mobile terminal changes its connection point to the access network ("point of attachment"), for example, a base station or an access point [1]. A handover process can be split into three stages: handover decision, radio link transfer and channel assignment. Handover decision involves the decision to which point of attachment to execute a handover and its timing. Radio link transfer is the task of forming links to the new point of attachment, and channel assignment deals with the allocation of resources. Depending on the type of network technologies involved, handoff can be classified as either horizontal or vertical. Traditional handoff, also called horizontal or intra-system handoff, occurs when the UE switches between different BSs or APs of the same access network. For example, this typically happens when the user moves between two geographically adjacent cells of a third generation (3G) cellular network. On the other hand, vertical handoff or inter-system handoff involves two different network-interfaces representing different wireless access networks or technologies, e.g., BS in IEEE 802.16 and an AP in IEEE 802.11.

Handover also can be classified as hard and sot handover. This classification of handoff depends upon the number of BSs and/or APs to which an MS is associated with at any given moment. Hard handoff, also called "break before make", involves only one BS or AP at a time. The MS must break its connection from the current access network before it can connect to a new one. In a soft handoff, also called "make before break", an MS can communicate and connect with more than one access network during the handoff process. A variety of Vertical Handover Decision (VHD) algorithms have been proposed in the literature to trigger handover at the optimal time to the optimal network based on a variety of network parameters. Handoff algorithms can be classified based on handoff criteria and their processing.

In [2], three vertical handoff algorithms based on RSS are discussed. First, algorithm is adaptive lifetime based vertical handoff, which combines RSS and estimated lifetime (expected duration after which the mobile terminal (MT) will be able to maintain its connection with WLAN) to decide the vertical handover. Second algorithm, is based on dynamic RSS threshold which is more suitable for handover from WLAN to 3G network. Third algorithm is a traveling distance prediction method, which works well for WLAN to cellular networks and vice versa. The third algorithm avoids unnecessary handoff and also minimizes failure probability.

In [3] the authors presented a survey of the vertical handover decision (VHD) algorithms designed to satisfy the required Quality of Service (QoS) to a wide range of applications. They categorized the algorithms into four groups based on the main handover decision criterion used and evaluated tradeoffs between their complexity of implementation and efficiency.

In [4], an innovative method is used to select the optimal network from available networks that achieves the better QoS performance. The aggregation of multiple criteria for calculation of overall ranking of networks is obtained by an Analytical Hierarchy Process (AHP) to resolve the issue of inconsistency. Weights are assigned to different criteria and aggregates of the weighted criteria are used to obtain the final ranks of alternative network. Results indicate that the delay is the important criterion during the handover process and WLAN is the optimal network among WiMAX and UMTS. Hence, it provides better QoS to the network as it reduces the overall delay in the network.

In [5], the authors proposed a handover decision algorithm using Media Independent Handover (MIH) mechanism services in Wi-Fi and WiMAX networks with QoS provision. The proposed algorithm not only uses RSS values as trigger and threshold, it also considers more additional important factors: price, bandwidth, delay, error rate and jitter. The proposed algorithm resulted in improvement for all four traffic classes. The simulation results showed that the proposed algorithm provides smaller handover times and lower dropping rate than the basic vertical handover method.

In [6], the authors presented an adaptive vertical handover algorithm based on Fuzzy Analytic Hierarchy Process (FAHP). The algorithm selected best network using cost function. Each attribute has a different weight according to its importance to users. FAHP was used to dynamically adjust the weights of each attribute according to users' preferences and the power state of the mobile terminal. The mobile terminal (MT) could access the best network that matches users' requirements. The simulation results showed that this algorithm can reduce the number of handovers.

In [7] shows the relationship between number of handover and time to trigger (TTT). The Fig shows that as the TTT increases, the number of handover decreases. The proposed method shows less number of handover for all the values of TTT. This is good result; this means that unnecessary handover is reduced.

In [8], the authors used game-theoretical models to study the radio resource allocation issues in device-to-device(D2D) communication. The D2D devices can compete or cooperate with each other to reuse the radio resources in D2D networks. Therefore, resource allocation and access for D2D communication can be treated as games. Game models can provide distributed solutions to the resource allocation problems for D2D communication.

In [9], the authors evaluated the mobility performance of Het Nets with the 3rd Generation Partnership Project (3GPP) Release-10 range expansion and enhanced inter-cell interference coordination (eICIC) features such as Almost Blank Subframes (ABSFs). The authors proposed a mobility-based inter-cell interference coordination (MB-ICIC) scheme, in which picocells configure coordinated resources so that macrocells can schedule their high-mobility UEs in these resources without co-channel interference from picocells to mitigate handover failures and ping-pongs.

The author in [10] discussed frequency reuse and measurement procedure for handover. A simple ICIC scheme had been proposed and evaluated its performance on the basis of handovers in LTE. The author showed that optimum HO performance can be achieved through optimum parameters selection by finding a compromise between HO rates and Residual Block Error Rate (BER) for HO command message.

G¨uvenc [11] used Range expansion and inter-cell interference coordination (ICIC) and improved the capacity and fairness of heterogeneous network (HetNet) by off-loading macrocell users to low-power nodes. Off-loading benefited of range expansion in HetNets was captured through cumulative distribution functions (CDFs) of the downlink signal to interference plus noise ratio (SINR) difference between the macrocell and strongest picocell signals. Then, these CDFs are used to investigate the system capacity and fairness as a continuous function of the range expansion bias.

In [12] the authors derived a handover failure (HF) expression as a function of L3 sampling periods in LTE. A geometric handover model was used for derivations and all analytical expressions were verified through simulations. In LTE, handover measurements are filtered using layer 3 (L3) filters in the UE. The UE checks for the handover entry condition at discrete sampling instants of the L3 filter. The selection of sampling period had become crucial in improving the handover performance of the network.

In [13], the authors characterized the relation between handover failure and ping-pong rates in a 3GPP heterogeneous network scenario as a function of relevant system parameters such as time-to-trigger, user equipment velocity, range expansion bias, etc. Under the assumptions that the picocell coverage and radio link failure areas are circular regions, and that users follow linear trajectories, handover failure and ping-pong rates are derived in closed-form expressions.

3. VERTICA LHANDOVER AND TARGET SELECTION IN 4G

The process of making decisions while taking into account more than one criterion is a common task and occurs frequently. Network selection problem exhibits the same characteristic and can be classified as Multi Attribute Decision Making (MADM) problem whose goal is to find a network among a set of candidates that can maximize end-users' satisfaction.

3.1 WEIGHTS CALCULATION USING ANALYTICAL HIERARCHY PROCESS (AHP)

AHP performs pairwise comparisons between the attributes, transforms these comparison scores into weights of decision criteria, prioritizes all alternatives on each criterion to obtain the overall ranking of alternatives. It consists of the following steps [14]

1. *Determination of the objective and the decision factors*: In this step, the problem is divided into a hierarchal structure comprised of the main objective, decision attributes, and the available alternatives.

2. *Determination of the relative importance of the decision factors*: During this phase, pairwise comparisons between the attributes at each level of the hierarchy are made. These comparisons are based on how strongly an attribute influences the other attribute in the pair. Table.1 depicts a fundamental scale that can be used to perform these comparisons.

The comparison results are formulated in a square matrix $A = [\, a_{ij}]_{nXn}$ where $a_{ij} = 1$, $a_{ji} = \frac{1}{a_{ij}}$, $a_{ij} \neq 0$ and n represents the number of decision attributes.

3. *Normalization and Calculation of the relative weights*: In this step, relative weights (w) are calculated by normalizing column vector if the matrix is cons$istent$ $(rank = 1)$.

4. The eigenvalues are calculated by solving

$$\det(\lambda I - A) = 0 \quad (1)$$

Then the normalized weight vector can be obtained as follows:

$$AHP_{matrix} * w = \lambda_{max} * w \quad (2)$$

λ_{max} *and* w Are the largest eigenvalue and eigenvector of the AHP matrix respectively. The w after normalization is the weight vector needed. The Consistency Index (CI) and Consistency Ratio (CR) can be used to find these inconsistencies. They are defined as follows:

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (3)$$

$$CR = \frac{CI}{RI} \quad (4)$$

Where$n$ is the number of elements being compared, and RI is the Random Consistency Index that is chosen based on the value of n. In practice, $CR \leq 0.1$ is considered acceptable; otherwise the subjective judgment of the decision makers related to the pairwise comparisons needs to be revised.

Table **1.** AHP Fundamental Scale of Importance

Intensity of Importance	Definition
1	Equal Importance
3	Moderate Importance
5	Strong Importance
7	Very Strong Importance
9	Extreme Importance
2,4,6,8	Intermediate Values

Fig 1 shows the hierarchal structure of all the attributes and sub-attributes utilized by our scheme. The development of this hierarchal structure is the first step towards using AHP. In this method network parameters; RSS, Delay,Cost, Security and power can be adopted to establish a hierarchical structure, and to build a comparision judgment matrix as below.

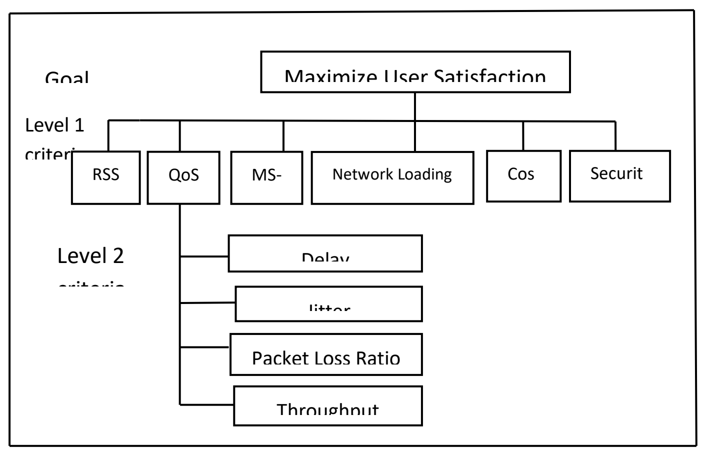

Fig.1. AHP Hierarchal Structure for VHITS

3.2 Cost Calculation

In the network decision stage, all parameters of the candidate networks will be taken into account. The cost function formula is shown in equation (4). Through comparing the cost function value of current network with that of a candidate network, the priority of the networks is decided.

$$Cost_n = w_{delay} \log(Delay_n) + w_{BER} \log(BER_n) + w_{BW} \log\left(\frac{1}{BW_n}\right) + w_{Jitter} \log(Jitter_n) \quad (5)$$

3. SYSTEM MODEL

A mobility model is used to simulate the mobility of MS within each cell. User mobility trajectories are characterized by the Random Way Point (RWP) model. The propagation model is the most important model, as the performance of any wireless communication system depends on how well the radio waves propagate through the medium. Hence, a propagation model is developed that considers different losses and gains during the signal propagation between the MS and the BS/AP. The proposed radio propagation model that is used in the work considers path losses due to signal attenuation based on distance, antenna gain, and both shadow and Rayleigh fading. This model can be defined as the logarithmic sum of all of these components. This is given in Equation (5).

$$G = G_{Path\_LOSS} + G_{Antenna} + G_{Shadow} + G_{Rayleigh} \quad (6)$$

As the distance between the MS and the BS/AP increases, the wireless signal attenuates. This signal attenuation is modeled using Hata Path Loss model [18] and is given in Equation (7).

$$G_{Path\_LOSS} = 10 \times \eta \times \log_{10} d + c \quad (7)$$

where $\boldsymbol{d}$ is the distance between the transmitter and the receiver, $\boldsymbol{\eta}$is the path loss exponent that relates the transmittedpower decay with distance, and $\boldsymbol{c}$ is a constant accounting for different system losses depending on carrier frequency, the size of the antenna, and other physical parameters [22].

The path loss models used in the proposed model is suitable for application in mainly urban areas [19] and is given by equation (8).

$$L[dB] = 128.1 + 37.6 \log[d(km)] \quad (8)$$

$$L[dB] = 39 + 20 \log[d(m)] \ , \ 10m < d < 45 \quad (9)$$

$$L[dB] = -39 + 67 \log[d(m)] \ , \quad d > 45m \quad (10)$$

In the above path loss model, (8) is used for macrocells while (9) and (10) are used for computation of path loss in micro cells. Here, d refers to the distance between mobile users and base stations.

4. RSS MEASUREMENT AND PROCESSING

In LTE systems, the handover mechanism is based on DL RSS measurements of the UE’s neighboring cells. Linear averaging is used to reduce the effects of fading. This linear averaging is done in layer 1 (L1) filter and Fig.2 shows the model for the processing of RSRP measurements through L1 filtering. Typically L1 filtering is done by obtaining RSRP samples every 40 ms and further averaging over five successive RSRP samples. Therefore, L1 filtering performs averaging over every 200 ms, equation (11) [12].

$$M(n) = \frac{1}{5}\sum_{k=0}^{4} RSRP_{L1}\,(5n-k) \quad (11)$$

UE further averages the L1 samples through a first-order infinite impulse response (IIR) filter and this filtering is called L3 filtering which is given by equation (12)[12,13]

$$F(n) = (1-a)F(n-1) + 10\,a\log_{10}[M(n)] \quad (12)$$

$\boldsymbol{a} = (\frac{1}{2})^{K/4}$, where k is L3 filter coefficient.

The UE checks the RSRP of candidate BSs at discrete time intervals of duration T_d (e.g., 200 ms in 3GPP LTE) before initiating the time-to-trigger (TTT). This is typically referred to as the L3 sampling period in the 3GPP LTE standard. If the sampling period T_d is too large, then a UE may have to wait for a long time until the handover condition is satisfied. Due to the high mobility of the UE, it may experience a handover failure (HF) due to degraded link quality before TTT is actually triggered. Therefore, the sampling period of the L3 filter should be small for high velocity UEs and selection of sampling period is essential in improving the handover performance of the network [13].

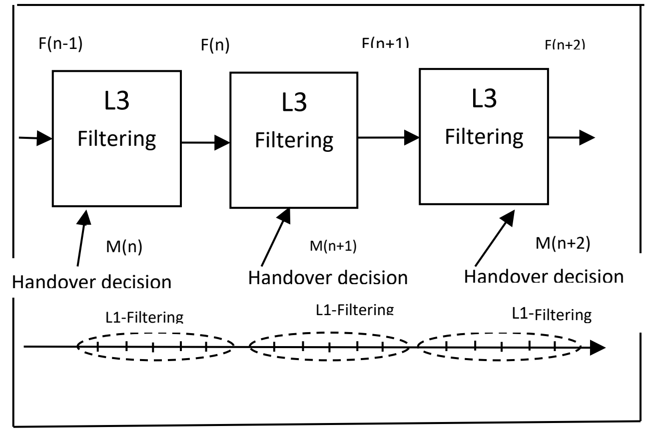

Fig .2. L1 and L3 filtering procedures [12]

5.1 REGRESSION ANALYSIS FOR RSS SMOOTHING AND PREDICTION

Regression analysis is a statistical technique for modeling and investigating the relationships between an outcome or response variable and one or more predictor or repressor variables. In the proposed model, this method is used for estimation of future values of RSS and for reducing the effects of deep fade; signal smoothing and estimation. Simple linear regression model involves a single predictor variable and is written as [22]

$$y = \beta_0 + \beta_1 x + \varepsilon \quad (13)$$

Where $\boldsymbol{y}$ is the predicted RSRP, x is the predictor variable. The distance between the mobile user and the base station is the predictor variable, x. The parameters $\boldsymbol{\beta_0}$ and $\boldsymbol{\beta_1}$ are unknown, and $\boldsymbol{\varepsilon}$ is the error term. The model parameters or regression coefficients $\boldsymbol{\beta_0}$ and $\boldsymbol{\beta_1}$ have a physical interpretation as the intercept and slope of a straight line, respectively. The slope $\boldsymbol{\beta_1}$ measures the change in the mean of the response variable *y* for a unit change in the predictor variable *x*. These parameters are typically unknown and must be estimated from a sample of data.

The error term accounts for deviations of the actual data from the straight line specified by the model equation. We usually think of εas a statistical error, so we define it as a random variable and will make some assumptions about its distribution. For example, we typically assume that $\varepsilon$is normally distributed with mean zero and variance $\boldsymbol{\sigma^2}$, abbreviated $\boldsymbol{N}(\boldsymbol{0}, \boldsymbol{\sigma^2})$.

The fitted values of the RSS from the regression model are computed from [22]

$$y = X \quad (14)$$

Where the least squares estimator $\boldsymbol{\hat{\beta}}$

$$\hat{\beta} = (\mathrm{X}'\mathrm{X})^{-1}\mathrm{X}'y \quad (15)$$

Where $\mathbf{X}'$ is the transpose of **X.**

5.2. Forecasting of New observation

The least squares normal equations for this model are

$$\mathrm{T}\,\hat{B}_0 + \hat{B}_1\,\frac{T(T+1)}{2} = \sum_{t=1}^{\mathrm{T}} y_t \quad (16)$$

$$\hat{B}_0 \frac{T(T+1)}{2} + \hat{B}_1 \frac{T(T+1)(2T+1)}{2} = \sum_{t=1}^{T} t * y_t \quad (17)$$

By solving the two equations, we find

$$\hat{\boldsymbol{B}}_{\mathbf{o}} = \frac{2(2T+1)}{T(T-1)} \sum_{t=1}^{T} y_t - \frac{6}{T(T-1)} \sum_{t=1}^{T} t * y_t \qquad (18)$$

$$\hat{B}_1 = \frac{12}{T(T^2-1)} \sum_{t=1}^{T} t * y_t - \frac{6}{T(T-1)} \sum_{t=1}^{T} y_t \qquad (19)$$

The least squares estimates obtained from this trend adjustment model depend on the point in time at which they were computed, that is ,T. sometimes it may be convenient to keep track of the period of computation and denotes the estimates as functions of times, say $\hat{B}_o(\mathrm{T})$ and $\hat{B}_1(\mathrm{T})$

The model can be used to predicts the next observation by predicting the point on the trend line in period (T+1), which is $\hat{B}_o(\mathrm{T}) + \hat{B}_1(\mathrm{T})(\mathrm{T}+1)$

And adding to the trend a forecast of the next residual, say , $\hat{e}_{\mathrm{T}+1}(\mathrm{T})$

If the residuals have no structure and have average value zero, the forecast of the next residuals would be zero. Then the forecast of the next observation would be

$$y_{t+1} = \hat{B}_o(\mathrm{T}) + \hat{B}_1(\mathrm{T})(\mathrm{T}+1) \qquad (20)$$

If the error is considered equation(19) is modified as equation (20)

$$y_{t+1} = \hat{B}_o(\mathrm{T}) + \hat{B}_1(\mathrm{T})(\mathrm{T}+1) + \hat{e}_{\mathrm{T}+1}(\mathrm{T}) \quad (21)$$

5. LEVEL CROSSING RATE AND AVERAGE DURATION OF FADE

The received signal in mobile radio communications often undergoes heavy statistical fluctuations, which can reach as high as 30 dB and more. In digital communications, a heavy decline of the received signal directly leads to a drastic increase of the bit error rate. Suitable measures for this are the level-crossing rate and the average duration of fades.

The *level-crossing rate*, denoted by $\boldsymbol{N}_{\zeta}(\boldsymbol{r})$, describes how often a stochastic process $\boldsymbol{N}_{\zeta}(\boldsymbol{t})$ crosses a given level $\boldsymbol{r}$from up to down (or from down to up) within one second [22].

value for the length of the time intervals in which the stochastic process $\boldsymbol{\zeta}(\mathbf{t})$ is below a given level $\boldsymbol{r}$. The average duration of fades $\boldsymbol{T}_{\zeta-}(\boldsymbol{r})$ can be calculated by means of [22]

$$\boldsymbol{T}_{\zeta-}(\boldsymbol{r}) = \frac{\boldsymbol{F}_{\zeta-}(\boldsymbol{r})}{\boldsymbol{N}_{\zeta}(\boldsymbol{r})} \quad \mathbf{(22)}$$

where$\boldsymbol{F}_{\zeta-}(\boldsymbol{r})$denotes the cumulative distribution function of the stochastic process $\boldsymbol{\zeta}(\mathbf{t})$ being the probability that $\boldsymbol{\zeta}(\mathbf{t})$is less or equal to the level $\boldsymbol{r}$ [22], i.e.,

$$F_{\zeta-}(r) = P(\zeta(\mathrm{t}) \le r) = \int_0^r p_{\zeta}(x)dx \qquad (23)$$

In the proposed, threshold crossing rate is examined and used in handover decision. If the threshold crossing rate is high this means that the handover is needed. Average duration of fade is used to compared the signal level when using the proposed algorithm and compared with the average duration of fade when using the AHP method.

6. Markov Chain

One approach for mobility prediction is using Markov Chain predictor. Markov Chain predictor is based on probability matrix that utilizes trajectory of the users that are stored in a database. The database consists of multiple available sources of information and is organized in the proposed data structure. In [23], the database is collected from user's data traces using logging report, which are then processed into transaction database. Then Markov chain equation is derived as:

$$\mathrm{P_n} = \mathrm{P_t}[\mathrm{P}]^{\mathrm{n}} \qquad (24)$$

Where,

P_t is initial distribution matrix,

P is current transition probability matrix,

n is number of state transition.

From the log file, the source-destination table is computed then the transactional database is developed. The transactional database shows a relationship between the source AP and the destination AP. This is the final step of the user's mobility history scheme before the value of the transactional database is utilized in the Markov Chain equation to predict the user's next location.

Then the source destination table is converted to a transactional database; which contain the number of movements from each network to other destinations. This transactional database is shown in Fig.3. The first column in the transactional database represents source AP and the first row represents destination access pointAP. The value of each relationship determines the frequency of user attached to each AP. The grand total is the total amount of user's transition from each base station to another. Once the transactional database is created, the Transition probability matrix (TPM) is generated.

TPM can be defined by dividing each value by the total value for each row in the transactional database. The value of transition probability is verified using summation for each row in the transactional database that should equal to 1.

Table **2.** Transactional Database

	LTE	**WLAN**	**WIMAX**	**Grand total**
LTE	0	1	3	4
WLAN	2	0	3	5
WIMAX	7	1	0	8

Table **3.** Transition Probability Matrix (TPM)

	LTE	**WLAN**	**WIMAX**
LTE	0	0.25	0.75
WLAN	0.4	0	0.6
WIMAX	0.875	0.125	0

The predicted results are then checked to mitigate an error in prediction. Ideal case in handover happens when mobile user handoff to the adjacent AP. However, if predicted AP is not adjacent to the previous AP, the predicted AP is considered an error. Because handover to adjacent (near) cell may be acceptable but handover to a cell that located far away may be wrong decision.

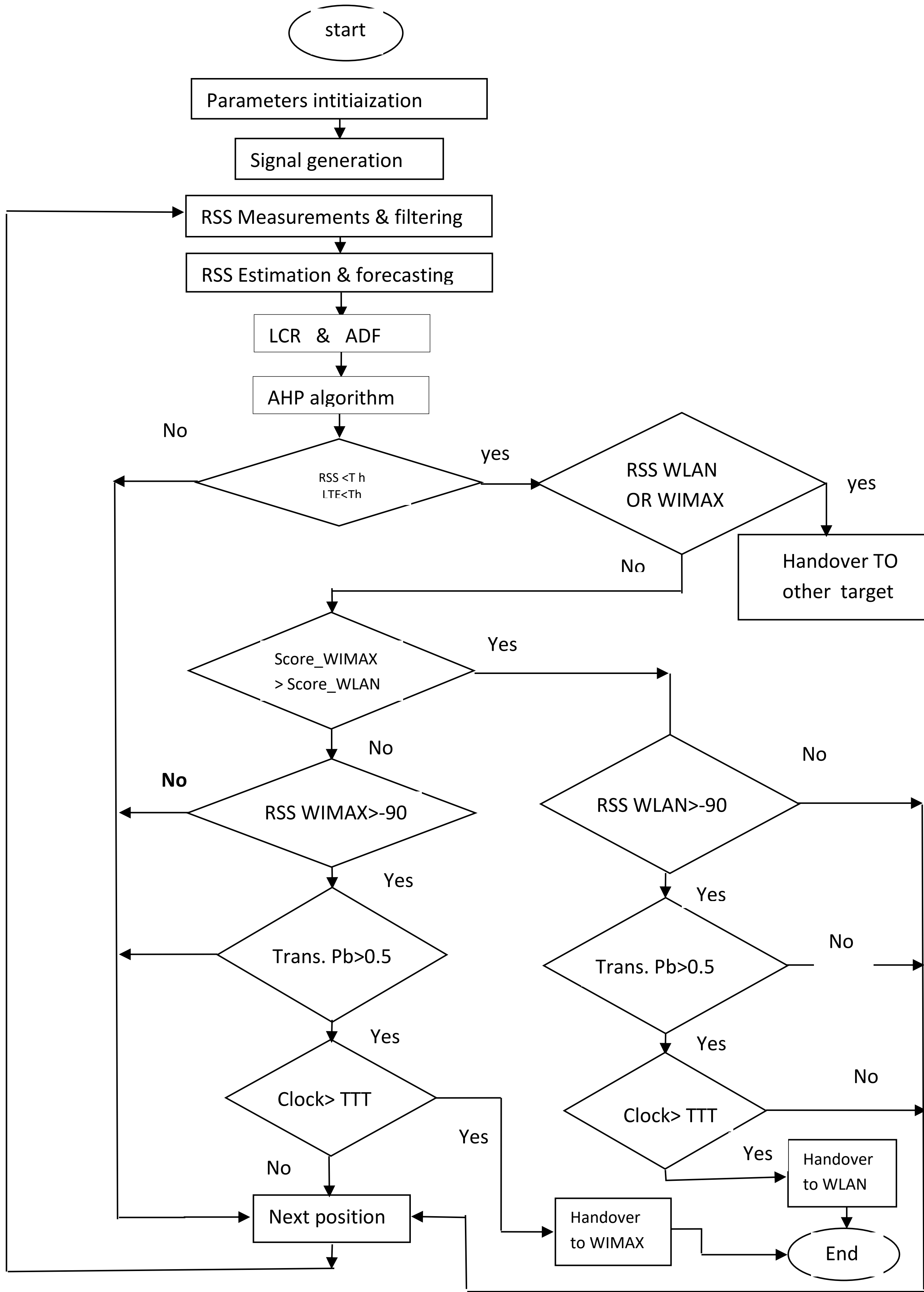

Fig .3. Flow Chart of the Proposed Algorithm

7. Results and Analysis

The model described in the previous sections has been simulated on a computer using Matlab software package. The parameters are shown in Table (4). These are typical values that are widely used in the published literature. A heterogeneous network is assumed to be composed of LTE network, Wimax network and WLAN network.

Table 4. System parameters that are used in the HO model

Simulation Parameter	Value		
	LTE	WIMAX	WLAN
No of mobile nodes	1		
Bandwidth (KHz)	1000	2000	1000
Tx power (dBm)	46	46	30
Mobile Speed (km/h)	10-100		
Cell radius (m)	500	800	150
Carrier frequency (GHz)	1000	2.5	2000
Throughput (Mbps)	1.42	1.18	1.48
BER (PER Kbytes)	0.008	0.008	0.010
Delay (s)	0.070	0.08	0.05
Jitter(s)	0.01	0.01	0.01
Price	20	20	10

Fig 4 gives a sample plot of the variation of the RSS of the three networks over time. The recurrence of deep fades associated with the multipath propagation is clear. The fade increases as the distance increases. The Fig also shows that the UE received the highest signal from the WLAN BS (the UE is near WLAN BS) and the signal going to decrease quickly and become the weakest signal compared to the other two signals.

Fig 5 shows the handover between the three networks for the conventional AHP algorithm. State1 (-1) represents that the user is connected to the WLAN, state (0) represents the user is connected to the LTE network and state (1) represents the user is connected to (Wimax) network. The Fig shows that, the user makes 3 handovers. The user connected to WLAN for (7 ms) and made handover and connected to LTE for (45 ms) and finally handed over and connected to Wimax for (48ms). So, the connection time for Wimax is the highest one, while the connection time for WLAN is the least one. This is because the coverage of the WLAN is narrow compared to the other two networks.

Fig 6 shows the handover between the three networks for the proposed algorithm. The Fig shows that, the user makes 2 handovers. The user connected to WLAN for (7 ms) and connected to LTE for (5 ms) and connected to Wimax for (88 ms). Therefore, the connection time for Wimax is the highest one, while the connection time for LTE is the least one.

Fig 8 shows the relationship between the threshold and connection time for the three networks.For LTE network, -80 dBm is the best threshold; that the user connects long time before making handover to other candidate network. For WLAN, -95 is the best threshold value. In WLAN, Rang Expansion is usually used; less threshold value, because the range of WLAN is very narrow. For Wimax network, threshold -90dBm gives the highest connection time. The results also shows that the most time user is connected to LTE OR Wimax, the WLAN is least connection time spent in the WLAN. This is true because of the converge of networks.

Fig 9 looks similar to Fig 8. LTE network shows connection for all the threshold value where as in Fig 5.8 at -90 dBm the user not connects to LTE.

Fig 10 shows connection time for the LTE network for different values of threshold values for the AHP method and the proposed method. The Fig shows that -80 dBm shows the best value; user connects to LTE for long time in the two algorithm. The Fig also shows that at high threshold values the proposed method gives higher connection time compared to the AHP.

Fig 11 shows connection time for the Wimax network for different values of threshold values for the AHP method and the proposed method. The Fig shows high values for the connection time excepts at Th=-80 dBm where the user handed over to LTE. Also the proposed algorithm gives higher connection time (from 2-18 s) compared to AHP method. When comparing Fig 5.10 and 5.11 we see that the two Figs are opposite, when Wimax shows high connection time, LTE shows low connection time (for same threshold). This means that, we that we can balance the load between LTE and Wimax by offloading between them.

Fig 12 shows connection time for the WLAN network for different values of threshold values for the AHP method and the proposed method. This Fig shows that the connection time for the WLAN is the least compared to Wimax and LTE. This because the UE connected to Wimax and LTE for the most time.

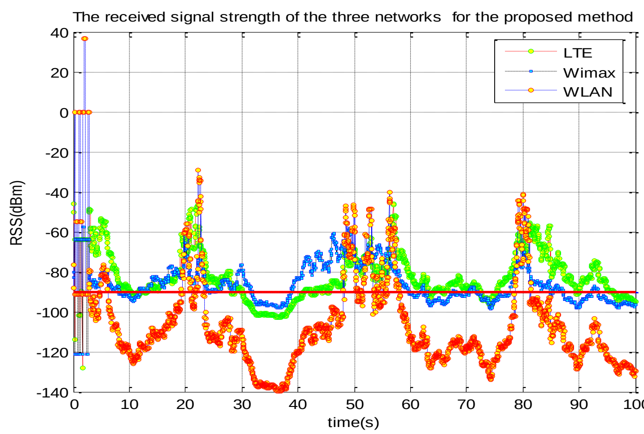

Fig .4. Received Signal Strength (RSS) of the three Networks

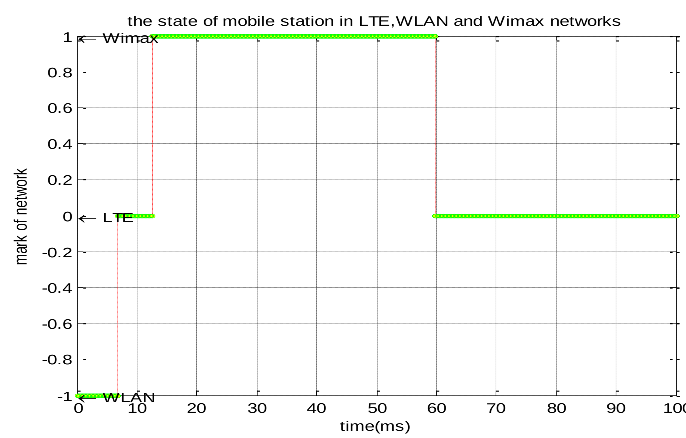

Fig .5. The handover between the three Networks using AHP Algorithm.

Fig 7 shows the relationship between number of handover and time to trigger (TTT). The Fig shows that as the TTT increases, the number of handover decreases. The proposed method shows less number of handover for all the values of TTT. This is good result; this means that unnecessary handover is reduced.

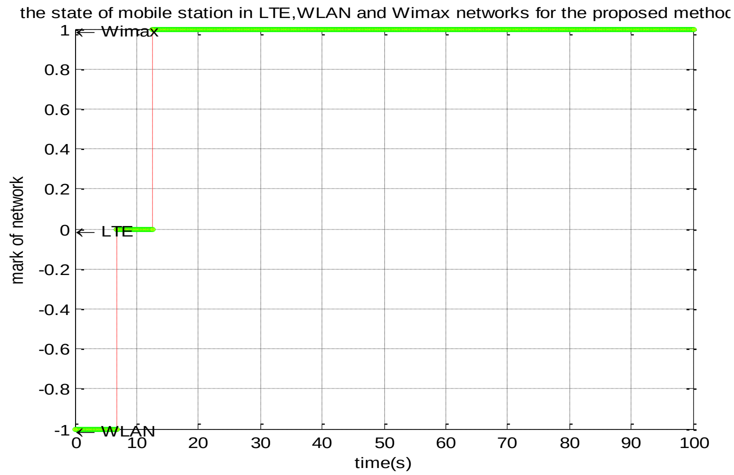

Fig .6. The handover between the three Networks using Proposed Algorithm

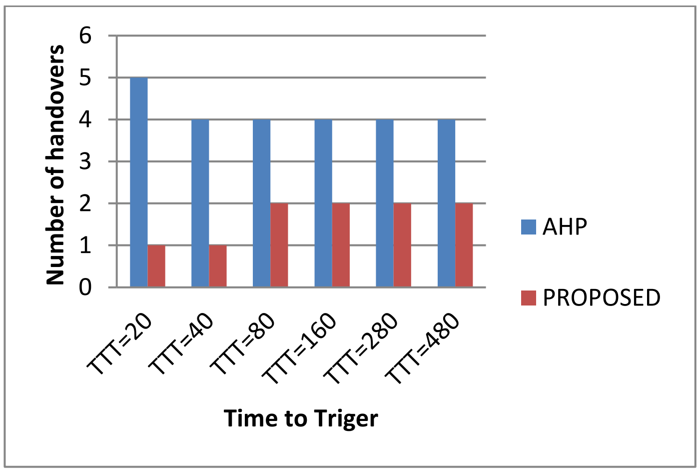

Fig .7. Relationship between Number of handover and Time to Trigger (TTT) for the AHP method and the proposed method

7.1 QoS Weights and Score

Table 5. QoS weights All Traffic Classes

Trffic class	Delay	Jitter	PLR	BW
Weight for Conversational	0.3292	0.3753	0.0938	0.2017
Weight for Interactive	0.26	0.131	0.3017	0.3074
Weight for Background	0.0498	0.1047	0.3554	0.4902
Weight for Streaming	0.0417	0.1751	0.1714	0.6118

Table 6. Score of the Three networks forAll Traffic Classes

Network	LTE	Wimax	WLAN
Score for Converational	0.8851	0.9172	0.9395
Score for Interactives	0.8823	0.9523	0.9299
Score for Background	0.8904	0.8765	0.8152
Score for Streaming	0.8731	0.9232	0.8439

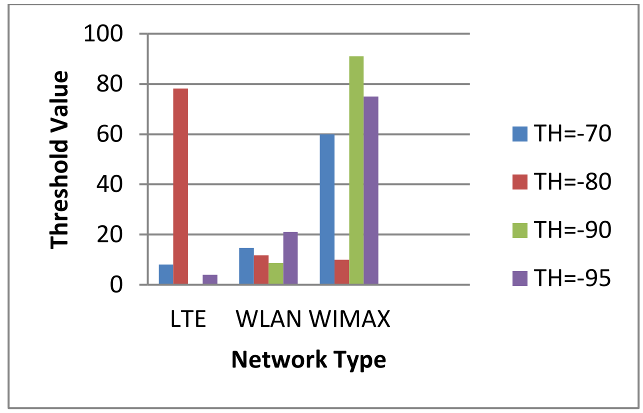

Fig .8. Connection time for the three networks for the AHP Method

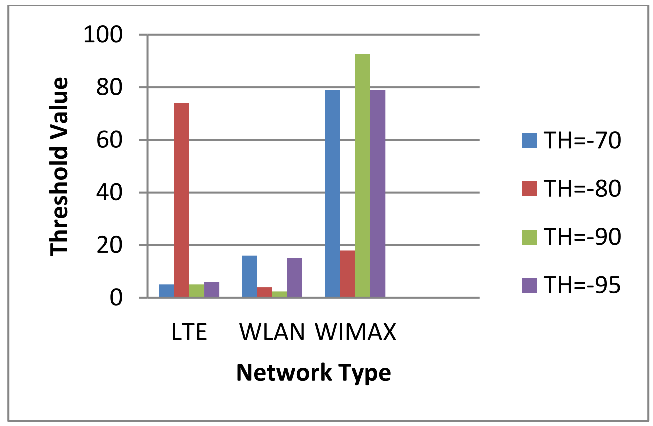

Fig .9. Connection time for the three networks for the proposed Method

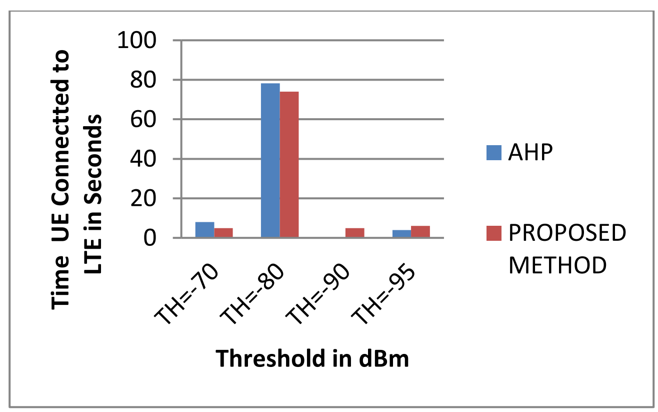

Fig .10. Connection time for LTE Network

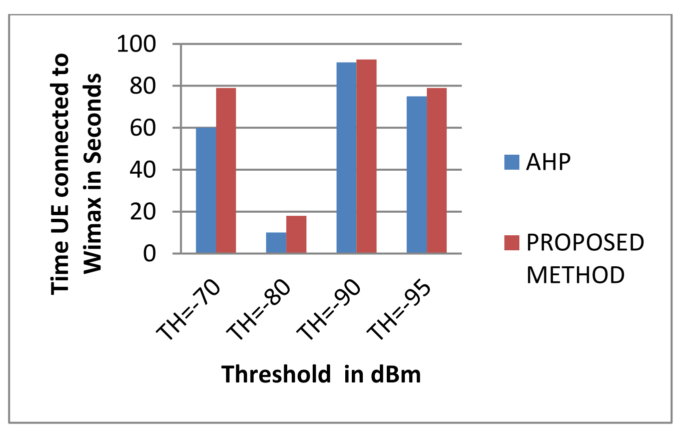

Fig .11. Connection time for Wimax Network

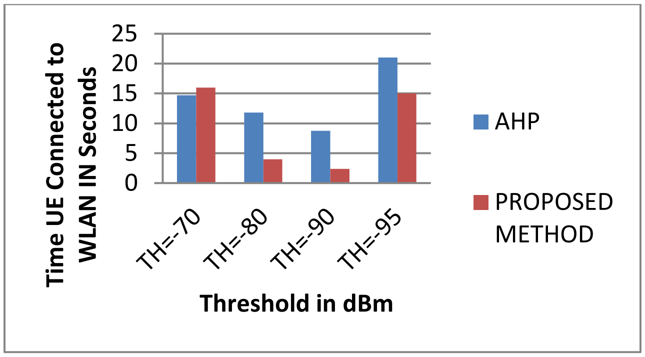

Fig .12. Connection time for WLAN Network

Fig 12 shows the relationship between the average duration of fade and user velocity for the proposed method and for the AHP method. For low velocity (10-50) Km/h , as the velocity increase the average duration of fade decreases. But for high velocity (70-120) the Fig show higher values for average duration of fade but is also decreasing with the increases of velocity. This results because the user first is connected to one network and then handed over to another network. The results also shows that the proposed method always gives lower average duration of fade compared to the AHP method. This is because signal smoothing used in the proposed method decrease the average duration of fade and hence improves the signal quality.

Fig 13 the relationship between average duration of fade (ADF) and the user velocity for the three algorithms; the proposed method, the proposed method but without RSS smoothing and the AHP. The results show that as the velocity increases the average duration of fade decreases. The results also show that the proposed method gives the better results; the lowest values of ADF compared to other two methods.

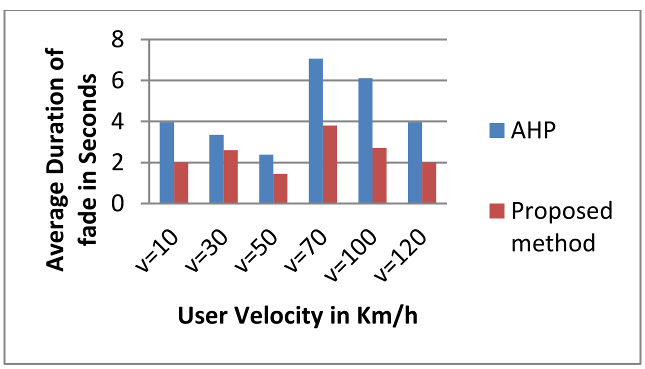

Fig .13. The relationship between average duration of fade and the user velocity

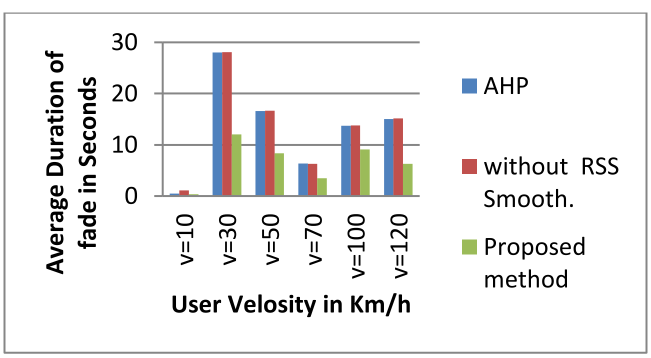

Fig .14. The relationship between average duration of fade and the user velocity for the three algorithms.

8. Conclusion:

Handover is one of the enhancement mechanisms that plays a central role in heterogeneous wireless networks. The proposed algorithm considers the history of visited cells for target selection combined with Analytic Hierarchy Process (AHP). AHP is used to adjust the degree of importance of each criteria in choosing the appropriate radio base station that the UE must connect to, allowing a more efficient handover decision (Multiple attribute Decision Making MADM). Weights are assigned to different criteria and aggregates of the weighted criteria are used to obtain the final ranks of alternative network. Regression analysis is a statistical technique for modelling and investigating the relationships between an outcome or response variable and one or more predictor or repressor variables. In the proposed method, this method is used for estimation of RSS and for reducing the effects of deep fade; signal smoothing. Simple linear regression model involves a single predictor variable (the distance between the UE and BS) is used for RSS prediction and smoothing.

It is not only important to know how often RSS crosses a given signal level per time unit, but also for how long on average the signal is below a certain level. Suitable measures for this are the level-crossing rate and the average duration of fades. Threshold level crossing rate and average duration of fade method is used in the proposed algorithm to mitigate deep fade effects and measure signal level and quality. Simulation results show that the proposed method delivered services better compared to the conventional AHP algorithms that found in the literature.

The results show that, the proposed algorithm minimizes the number of handover and unnecessary handover. The results also show that the threshold crossing rate and average duration of **fade is reduced** using the proposed algorithm when compared with the conventional AHP.

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