CHAPTER III

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QoS ENHANCEMENT BY USING INTELLIGENT HAND-OFF TECHNIQUE

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Efficient hand-off algorithm enhances the capacity and QoS of cellular systems. Hand-off algorithm is used in wireless cellular systems to decide when and which BS should receive the handoff call, without any service interruption. In this chapter, HAP has been considered as a complementary BS to terrestrial mobile system, giving coverage in shadow zones. HAPs can provide back-up services to uncovered areas of terrestrial systems, thus with the goodness of HAP, total capacity (QoS, in turn) in a service-limited area will be improved.

This chapter begins with the introduction of the concept of cellular deployment, hand-off and HAP movements. Subsequently, the basic theory behind specification parameters for QoS enhancement (i.e. time advance technique, MUSIC algorithm, RSS, distance and traffic intensity) has been given.

Further, recently Artificial Neural Network (ANN) has been utilized for efficient decision making in various hand-off algorithms due to its ability to learn from dynamically changing CAC and mobile user data. Also, once ANN has been trained well, they are able to take prompt decisions i.e. almost in real-time.

In this chapter Radial Based Function network (RBFN) has been used for making efficient hand-off decisions based on eight parameters viz. RSS from (original cell, neighbor cell, HAP), distance (original cell, neighbor cell), traffic intensity (original cell, neighbor cell) and directivity.

It is shown that the proposed algorithm decreases the number of unnecessary hand-off and therefore hand-off rate is improved

3.1. Introduction

Cellular communications provide communication facility to Mobile subscribers (Ms). A service area is divided into a number of cells [128]. Multiple cells constitute a cluster. The available frequency spectrum is used in each cluster. Each cell in a cluster uses a fraction of the available channels in the spectrum allocated according to a channel assignment strategy and is served by BS. In wireless environment, one of the key ingredients to provide efficient ubiquitous communication with guaranteed QoS is the design of intelligent hand-off algorithms.

Hand-off is a common technique employed by all cellular systems (both in terrestrial and satellite) for ensuring uninterrupted connectivity with increased system capacity, typically when the user moves from one cell to another cell or faces a shadow zone in one cellular technology yet supported under other cellular system, operational in coexistence [129, 130].

A properly designed hand-off algorithm is essential in reducing the switching load of the system while maintaining the desired QoS of the call in progress, seeking hand-off. The hand-off process determines the optimal threshold for sustained QoS for respective user in each cell [131].

The Hand-off algorithm can also exploit the unique characteristics of HAP which is coexisting with terrestrial cellular system as a back-up system. The integrated system of HAP with the terrestrial cellular system is shown in Figure 3.1.

In this Figure 3.1, the terrestrial base stations are shown as 1, 2, 3, 4 etc. when user in cell 2 moving to cell 7 but there is no empty channel in cell 7, handoff will perform to HAP. On the other hand, when user in cell 3 moves to out of terrestrial coverage, hand-off will be performed to HAP. Furthermore, user in cell 7 got weak signals from cell 7 and user still inside the cell in shadow zone; hand-off will perform to HAP.

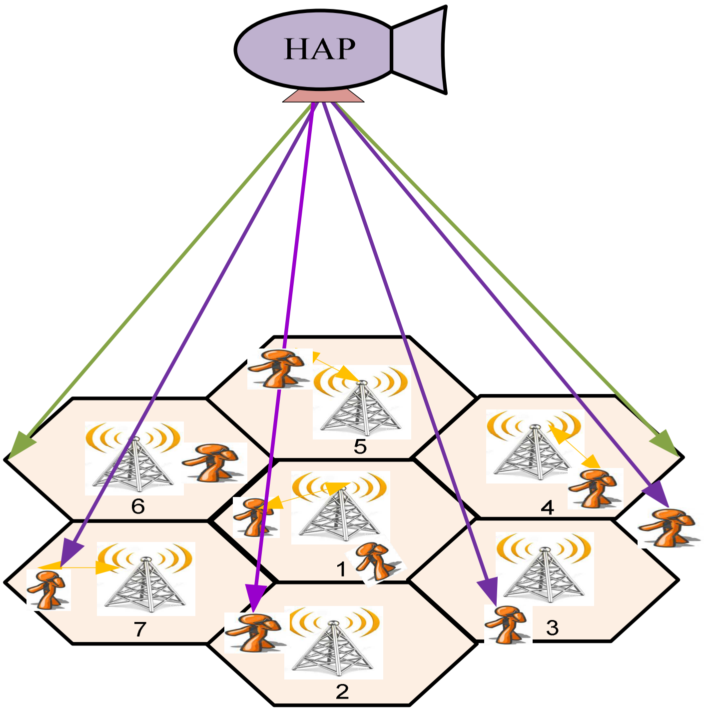

Figure 3.1 Concept of HAP based Cell Architecture

For making hand-off decision, the decision can be made based on various parameters. Taking more parameters in to consideration, that will make the decision more effective. The most manufacturers have designed their hand-off algorithms based on signal strength [132]. In this case, BER and the timing advance can act as alarm condition indicators rather than hand-off algorithm inputs. In particular, proper selection of the soft hand-off region and its associated parameters can avoid the ping-pong effect common in hard hand-off [133]. A list of parameters used as hand-off criteria in GSM is given here [134]. In addition, while performing vertical hand-offs, these algorithms do not take into account the QoS of an ongoing session to maximize the end-users' satisfaction based on their preferences, location and/or application contexts. Factors like available network bandwidth, latency, security, usage cost, power consumption, battery status of MS, and user preferences should be thoroughly considered while performing these hand-off decisions[135].

Recently, ANN has been applied to many diverse problems. Neural network is trained to predict a user's probability for a hand-off [136]. ANN helps in taking the hand-off decision based on RSS, availability of channels, direction, distance and etc. These parameters are used in various combinations to create the training and testing dataset. For each sample input of the training dataset, a target hand-off decision has also been predicted. Similarly, the testing dataset is also generated. The ANN is trained with this training dataset. Success of this training is tested by using the testing dataset. After satisfactory training and testing, the 'hand-off ANN' is capable of taking efficient hand-off decision, thereby reducing unnecessary hand-off and improve hand-off rate.

Therefore, we have proposed an algorithm for efficient hand-off between HAP and terrestrial mobile communication systems by using ANN. Further, in this contribution, HAP has been considered as a complementary layer for terrestrial mobile communication system. For superior decision making, the hand-off procedure has been augmented by using ANN and considering additional control parameters. It is shown that the proposed technique can significantly reduce the hand-off rate during hand-offs.

3.2. Cellular Concept

A general wireless communication network is provided with a bandwidth which is also known as the spread spectrum. This spectrum is limited and has to cover all the users present in the specific network. Coverage area is divided into cells also represented as hexagons cells. Each cell consists of a BS which serves for all the users present inside that cell, as shown in Figure 3.2. The bandwidth in wireless communication is divided into sub spectrums (the channels, cantered at different frequencies).

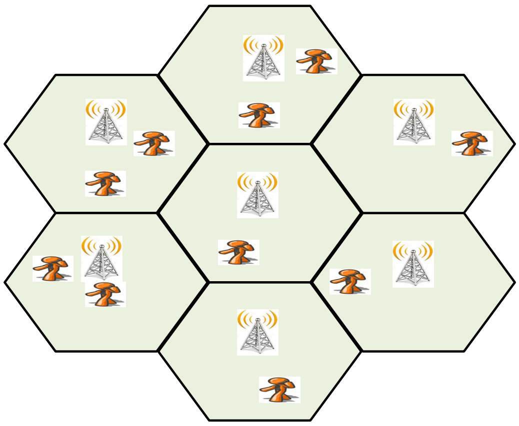

Figure 3.2 Concept of Cellular Wireless Network

3.3. HAP based Cellular Network Deployment

The HAP is expected to carry a set of antennas and other equipment as payload. This set of antennas cover a hexagonal area over the earth, by creating multiple cells. Figure 3.3 shows the hexagonal shaped cells as created by HAP using multi-beams.

In Figure 3.3, each cell is identified by a pair of coordinates [N_r,N_c]. N_r specifies the number of concentric hexagonal ring or tier in which the cell is located, and N_c is the number of the cell within that tier, and it decreases clockwise. All tiers are disposed concentrically around the central cell as in Figure 3.3 depicts. At this step, the cell disposition has defined and hexagonal coverage of HAP is expected to provide with a set of antennas as payload.

One tier and two tier situations are shown in Figure 3.3. In case of one tier, the separation distance between cells is 8 Km. On the other hand, two tiers are used, the separation distance is 4 Km. So that, if the mount of tier increases, the separation distance between the cells decreases. So number of cells at any tier is given by:

$$N_{cell} = 6XN_r \qquad \text{Equation (3.1)}$$

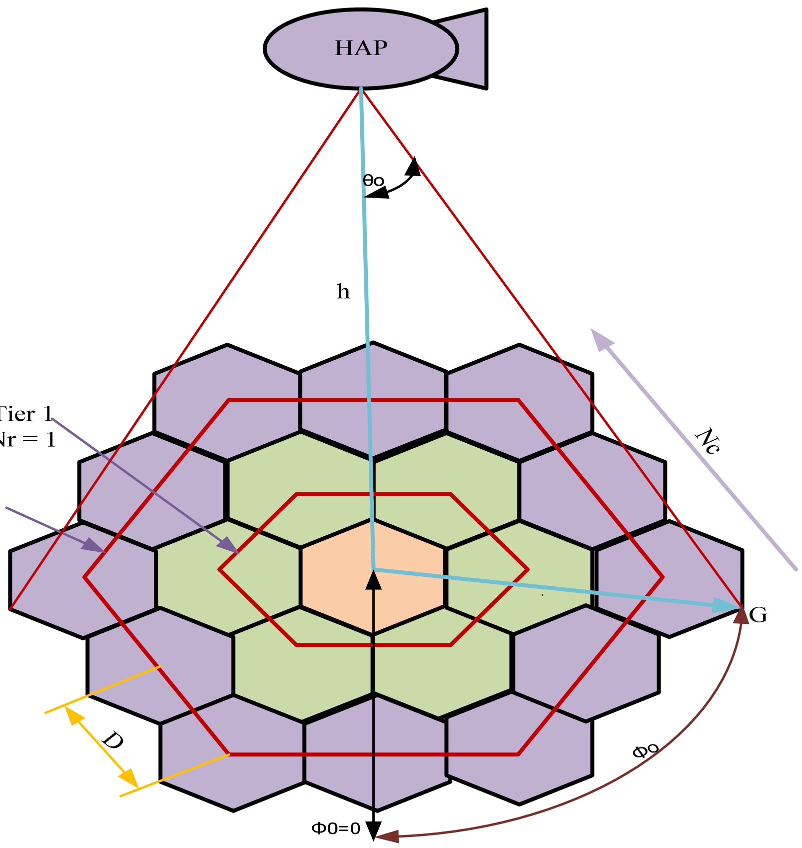

Figure 3.3 Cell Disposition and Parameters [108, 137]

In case of $N_r = 1$, the total number of cells is six and one reference cell as given below.

$$N_{cell} = 6X1 + refernce\ cell = 7\ cells \qquad \text{Equation (3.2)}$$

In case of $N_r = 2$, the total number of cells in the first tier and cells at second tier as given below.

$$N_{cell} = 6X2 + number\ of\ cell\ in\ first\ tier = 19\ cells \qquad \text{Equation (3.3)}$$

In case of $N_r = 3$, the total number of cells in the second tier and cells at the third tier as given below.

$$N_{cell} = 6X3 + number\ of\ cell\ in\ first\ tier \qquad \text{Equation (3.4)}$$

In case of one tier, the average number of served users for the configuration with is considered 661 [137]. Consequently, the service performance probability would be 661/ number of users. In case of two tiers, the average number of served users for the configuration with is considered 1774 [137]. Consequently, the service performance probability would be 1774/ number of users.

Next step is to define the azimuth and elevation angles from the HAP to the center of cell for these antennas. Figure 3.3 shows all parameters are required for any cell, whose coordinates are [N_r,N_c], the HAP height and D is the separation between cells [108]. The expressions of the elevation θ_0 and the azimuth angle $\emptyset_0$ can be drived from:

$$\theta_0 = \arctan\left(\frac{G}{h}\right) \qquad \text{Equation (3.5)}$$

$$\emptyset_0 = \arcsin\left(\frac{(c' - 1)Dsin\left(\frac{\pi}{3}\right)}{G}\right) + (N_s - 1)\frac{\pi}{3} \qquad \text{Equation (3.6)}$$

Where h is the HAP height and ground distance G is the distance from the cell centre to the subplatform point, which can be derived from:

$$G = \sqrt{(N_r.d)^2 + ((c' - 1).d)^2 - 2N_r.d^2.(c' - 1).\cos\left(\frac{\pi}{3}\right)} \qquad \text{Equation (3.7)}$$

In this expression c' is used to identify the cell's location with respect to the first cell along the side:

$$c' = N_c - (N_s - 1).N_r \qquad \text{Equation (3.8)}$$

Where $N_s$is an integer between one and six identifying the side of the hexagon:

$$N_s = 1 + floor[\frac{N_c - 1}{N_r}] \quad \text{Equation (3.9)}$$

With all these parameters it is possible to define the antenna azimuth and elevation angles for all cells that comprise the hexagonal structure [108].

As stated in the geometry represented in Figure 3.4, the XY plane represents the earth surface and the Z − axis symbolizes the platform height h, the distance between the Sub-Platform Point (SPP) and the center of the cell is represented by g but that from the outer circle to the hexagonal cell is given by r. θ_{sub} represents the elevation angle and $\emptyset_{sub}$ is the azimuth angle of beam. The angle θ_{sub} and $\emptyset_{sub}$ can be calculated by the following:

$$\theta_{sub} = \arctan\left(\frac{g+r}{h}\right) - \arctan\left(\frac{g-r}{h}\right) \quad \text{Equation (3.10)}$$

$$\emptyset_{sub} = 2\arctan\frac{r}{\sqrt{g^2 + h^2}} \quad \text{Equation (3.11)}$$

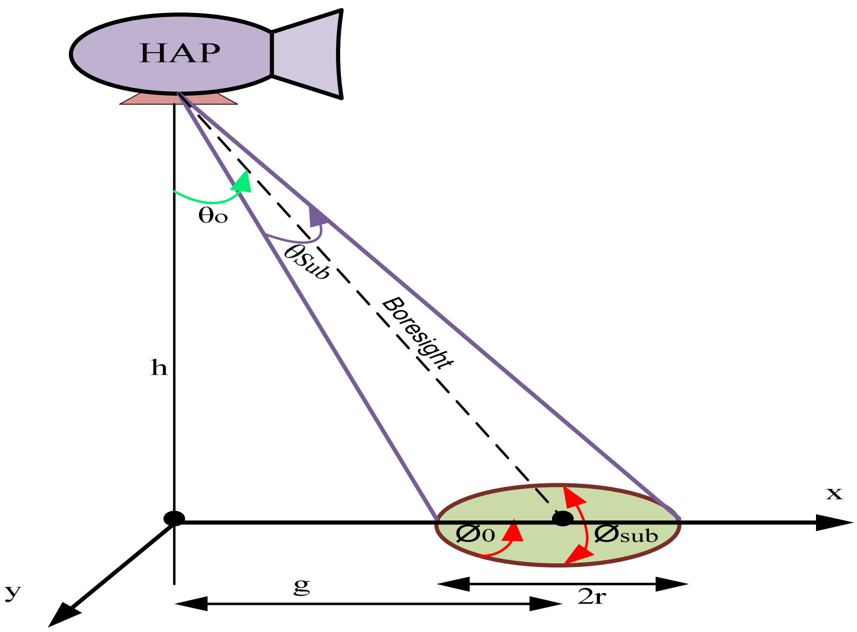

Figure 3.4 Cell Geometry [108, 137]

The hexagonal cell of HAP coverage is depicted in Figure 3.4. The radius of hexagonal area on Earth is 10 Km [138]. The coverage of the cell is environment dependent. The environments may be UAC, SAC and RAC. Four main reasons for the reduction in the cell coverage are: reflection, diffraction, scattering and multipath [139].

When there are a large number of tiers, the distance between tier decreases, and the number of the cell increases. Therefore, the decrease in the distance between cells directly affects the overall network performance. The separation distance between cells is given by:

$$d = \frac{8\text{Km}}{\text{Number of tiers}} \qquad \text{Equation (3.12)}$$

HAP can deploy a multi-beam antenna capable of projecting memories spot beams with its potential coverage area. Therefore, QoS depends on the coverage area whilst coverage area depends on the shape of cells. Cell shape depends on antenna radiation pattern which used to determine the shape of cell. Therefore, different cells have different antenna radiation patterns. Thus, the performance of service probability analysis based on the distance between cells and antenna radiation patterns [137].

3.4. The Concept of Hand-off

Traditional single-metric hand-off decision algorithms, such as RSS, are not efficient and intelligent enough to minimize the number of unnecessary hand-offs, decision delays. Efficient hand-off algorithms cost-effectively preserve and enhance the capacity and QoS of communication systems [140].

Hand-off is a common technique employed by all cellular, which has been proven vital both for ensuring uninterrupted connections and increasing system capacity [141]. Hand-offs are expensive to execute, so unnecessary hand-offs should be avoided. There are several hand-off techniques proposed in the literature depending on the type of the channel allocation technique used. Hand-offs can be classified as fixed [142], flexible [143] and dynamic [144]. These techniques are used for new connection and hand-off connection requests. Also the technique for predicting user mobility remains a very challenging task due to the fuzziness of human mobility patterns has investigated [145].

3.4.1. Desirable Features of Hand-off

A seamless hand-off is typically characterized by two performance requirements [146] are:

a. The hand-off latency should be no more than a few hundreds of milliseconds.

b. The QoS provided by the source and target access networks should be nearly identical in order to sustain the same communication experience.

Figure 3.5 describes several desirable features of hand-off algorithms as mentioned in the literature [147].

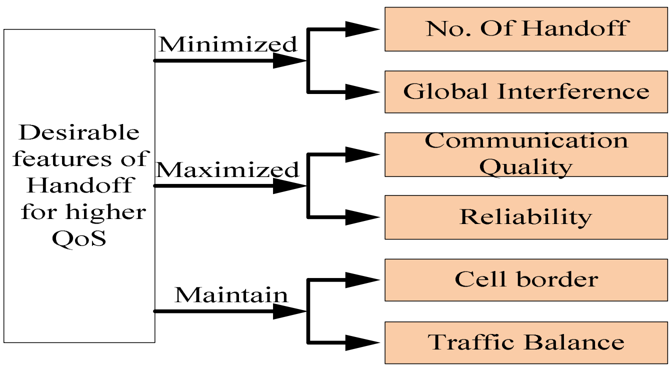

Figure 3.5 Desirable Hand-off Features [148]

3.4.2. Classification of Hand-off

The hand-off process determines the maximum number of calls that can be served in a given area [149]. Figure 3.6 shows a simple hand-off scenario in which an Ms travels from BS-A to BS-B. Initially, the Ms is connected to BS-A. The overlap between the two cells is the hand-off region in which the mobile may be connected to either BS-A or BS-B. At a certain time during the travel, the mobile is handed-off from BS-A to BS-B, when the Ms is close to BS-B.

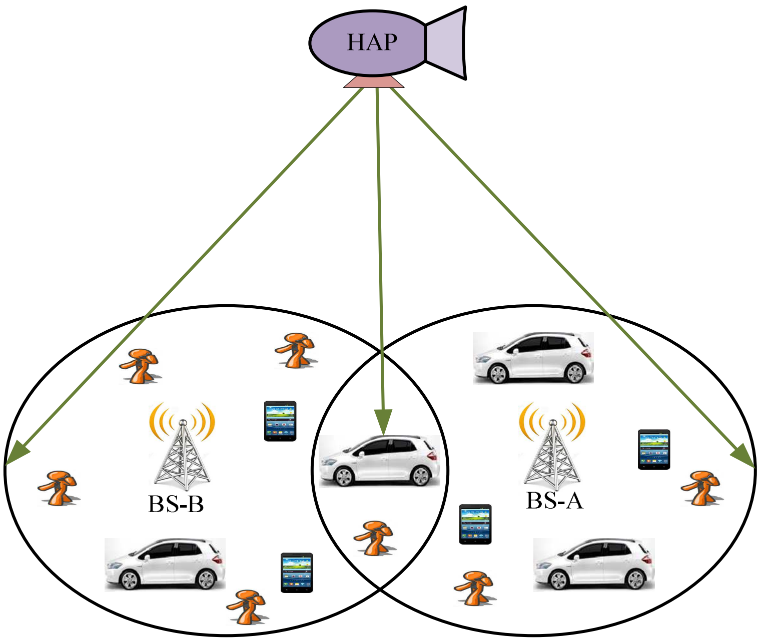

Figure 3.6 Hand-off Cellular System

Hand-off classification can be classified into several ways [150] depending on type of type of network, number of connection and entity. In the first type, Figure 3.7 represents as horizontal and vertical hand-off, hard and soft hand-off, mobile - controlled, mobile - assisted, and network - controlled hand-off.

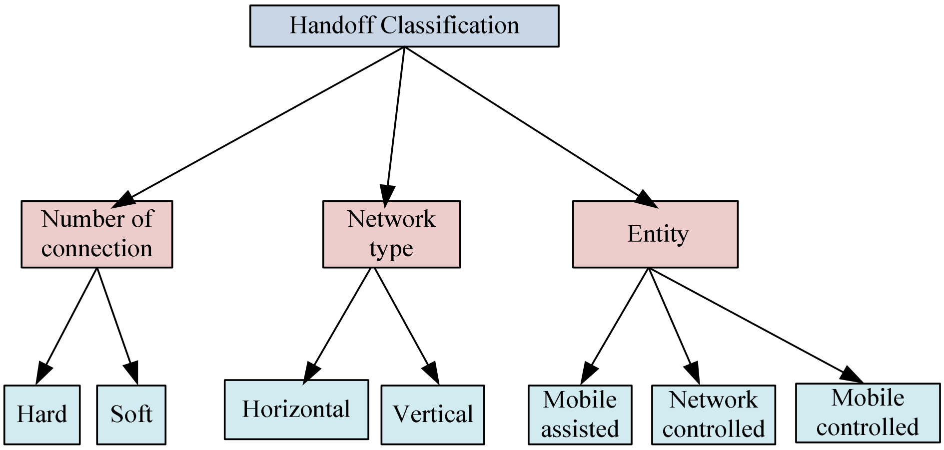

Figure 3.7 Hand-off Classification [148]

Horizontal hand-off occurs when the Ms moves between different BS of the same network. On the other hand, vertical hand-off occurs when hand-off is required between different wireless networks. Second type is number of connection which is represented by hard and soft. Hard hand-off, the Ms must break its connection from the current access network before it can connect to a new one. But the Ms can communicate and connect with more than one access network during the hand-off process in case of a soft hand-off. The third type depends on entity and represented by mobile-controlled, mobile-assisted, and network-controlled hand-off, mobile-assisted hand-off is the hybrid of mobile-controlled and network-controlled hand-off where the Ms makes the hand-off decisions in cooperation with the access network [148].

3.4.3. Hand-off Procedure

Hand-off includes three major steps i.e. hand-off initiation, channel assignment and execution [151]. Initiation phase, decision to start the hand-off procedure is taken. The execution phase, a new channel assignment is carried out but if there is no channel available, the call is dropped [152].

1. Hand-off decision / detection: a decision has to be made when exactly to initiate and perform a hand-off. This decision can be made by the user's equipment or by the BS.

2. Hand-off channel assignment: this phase has to manage the channels in order to ensure that there will be enough channels to minimize dropping probability.

3. Hand-off execution: this phase of a hand-off procedure includes the protocols for reliable exchange of handover data. This is the signaling procedure needed to inform the hand-off connection and BS about the new channel allocation.

There are several desirable features of hand-off as the following:

a. Hand-off algorithm should be fast.
b. Hand-off algorithm should be successful.
c. Hand-off algorithm should be maintained the planning cellular borders to avoid congestion.
d. The number of hand-off should be minimized.
e. Hand-off to target cell should be chosen correctly minimal.
f. Procedure of hand-off should be minimize the number of call drop.

3.5. HAP Movement

The position of HAP is not fixed and will vary with time depending on the prevailing winding conditions in the stratosphere. Investigation of the potential use of phased array technology was done in [153] to cope with platform movement. When the platform is moving, it would also be necessary to compensate motion by electronic or mechanical means in order to keep the cells stationary, or to "hand-off" connections between cells as is done in cellular telephony.

3.5.1. Vertical Shifting

HAP comprises individual antennas for individual cells on the ground which is fixed in relation to each other than coverage area on the ground has a subtended angle that is fixed as shown in Figure 3.8. In addition, the coverage area can be calculated by the following formula [79]:

$$\Delta A = \pi[(h + \Delta h)\tan\vartheta]^2 - \pi\,(h\tan\vartheta)^2 \qquad \text{Equation (3.13)}$$

Where ΔA is the coverage area, h is the altitude, Δh is change of high and ϑ is subtended angle which is fixed.

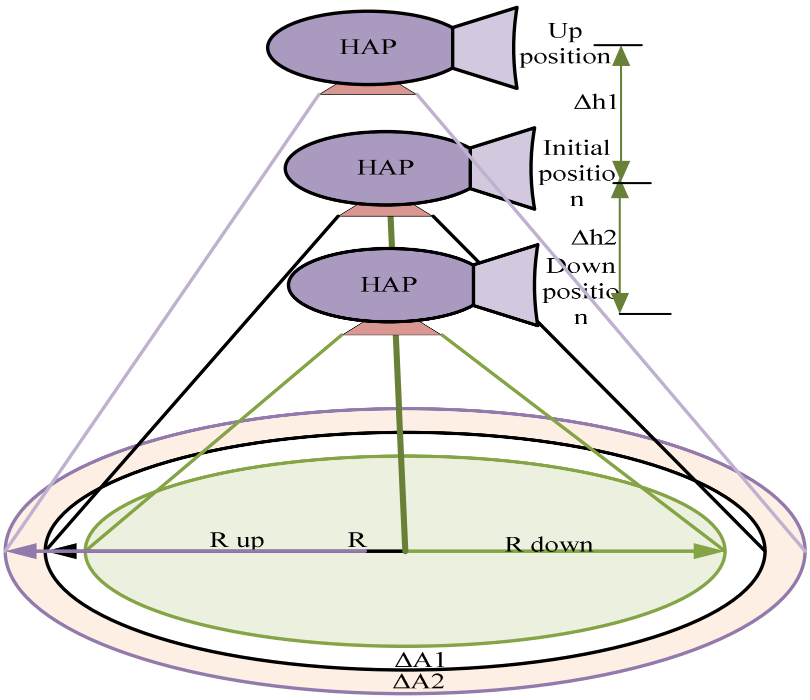

Figure 3.8 Vertical Shifting up and down of HAP

3.5.2. Horizontal Shifting

As shown in Figure 3.9, HAP movements can change position or distort the shape of the individual cells.

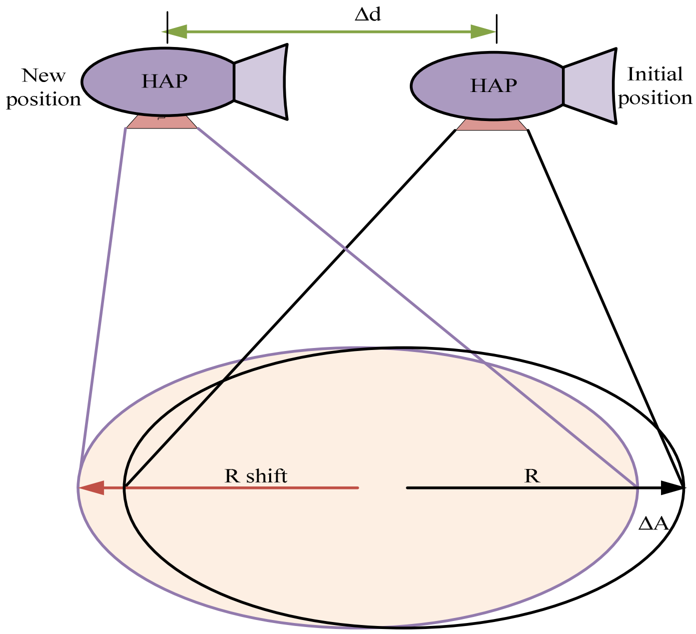

Figure 3.9 Horizontal shifting of HAP

In the case of the HAP, it drifts from the center of the coverage area and its cells move from their intended position. The coverage will increase in the direction of the platform and the user in the opposite direction will lose coverage. The approximate coverage is shown as follows:

$$\Delta A \approx disp(disp^2 - 4r)^{0.5} \qquad \text{Equation (3.14)}$$

Where r is the coverage radius and disp is the horizontal displacement.

3.5.3. Using Steerable Antenna for Hand-off

Steerable antennas can be used to cope with the movement of the HAP have been addressed in the past such as in [79, 80, 128] as shown in Figure 3.10. Axiotis et al. (2004) have proposed mechanism in order to counter balance the horizontal displacement with the ideal position of the HAP and the relevant correction required being specified using a GPS [80]. A steerable antenna correction mechanism has proposed, which needs to be applied on every antenna individually [79]. However, this would require a complex mechanical system with a large number of motors. Therefore, it would add significant weight to the payload.

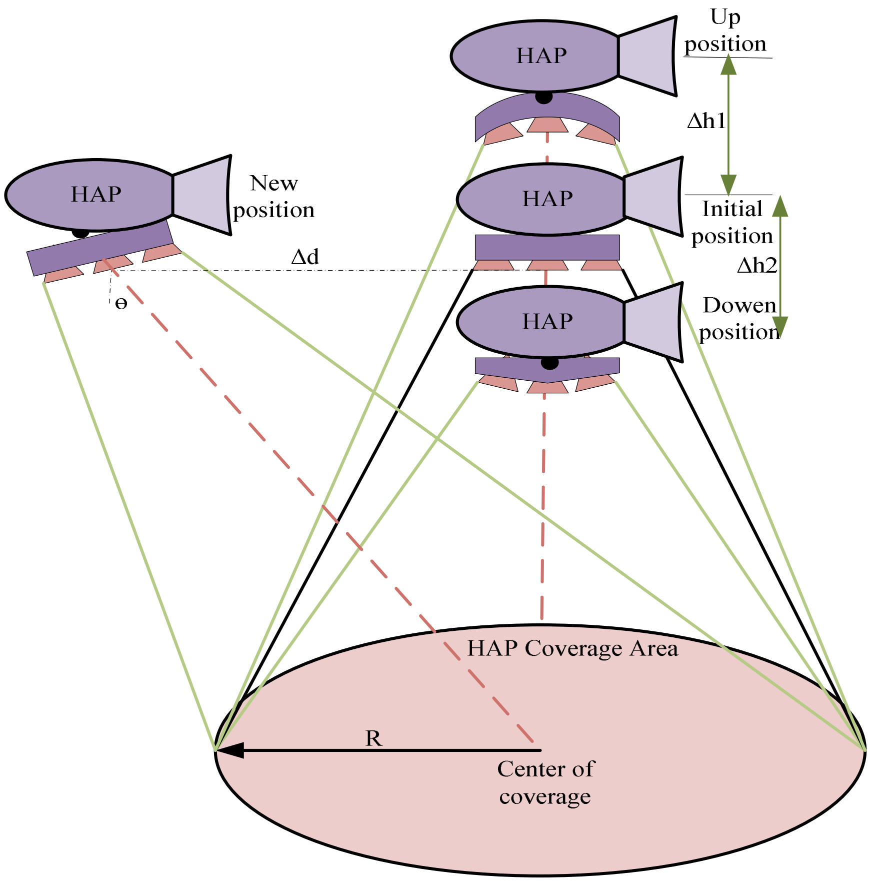

Figure 3.10 Steerable Antenna Solution for Hand-off

It was preferable that HAP would employ some sort of mechanically steerable mechanism but for a group of antennas instead. As shown in Figure 3.10, when HAP moves upward, the antennas will be pushed inward, and the center will move little upward. In the other hand, when HAP moves downward, the antennas will be pushed outward, and the antenna at the center will move a little downward.

In case of horizontal movement, the steerable antenna of the center cell is always pointing to the center of the HAP coverage area and all the antennas are interconnected with each other.

Theoretically, the easiest and simplest solution is the mechanically steered antennas, which gives good performance at low cost. However, high-speed steering may become challenging due to the large mass of such an antenna.

3.6. Antennas for HAP

Antennas are the most important element in the air to earth interface between HAP and Ms for several reasons. First, the antenna pattern defines not only a "footprint" and coverage but also the interference and Carrier Interference Ratio (CIR) values that affect directly the QoS and network performance. Second, due to the platform altitude, the antenna beam width must be of a few degrees in order to create a layout of cells [128].

As the size of cells decreases, the number of cells increases and also the required payload aperture increases. The size of the antenna array is also determined by the altitude of the platform for a specified radius of the central cell. As the altitude of the platform increases, the size of the array also increases [154] .

3.6.1. Antenna Radiation Pattern

An antenna is a conductor between a radiated wave and a guided wave or vice versa as well as to transmit, send and receive signals such as microwave, radio or satellite signals. Thus, radiated wave is characterized by the antenna's radiation pattern.

Generally, antenna arrays are used to obtain suitable directive characteristics in order to increase the radiation towards the serviced area and suppress it towards other ones. Usually the implementation of antenna have narrow main beam and side lobe beam which described [111]. Additionally, radiation properties are characterized by the horizontal radiation pattern and vertical radiation pattern. These two radiation patterns are used to estimate the gain of antenna.

Azimuth angle and elevation angle are used to determine antenna gain at any point in the footprint. Also, the antenna gain can be expressed as antenna loss, which is the difference between the maximum antenna gain and the gain in that direction. The capabilities of antenna radiation should be known in all the directions, to ascribe each point under the antenna covered area, the correct signal level and the exact antenna gain in that direction. Two different beam widths are used in this article: 2^0 and $5^0$are considered in this work for improve the performance of service probability. The expression of 5^0 antenna radiation pattern, based on [155], is given by:

$$G(\theta) = \begin{cases} 30.7 - 3(\theta/2.5^0)^2 & \text{dBi} \quad 0^0 \le \varphi \le 7.21^0 \\ 30.7 - 25 & \text{dBi} \quad 7.21^0 \le \varphi \le 8.68^0 \\ 62 - 60\log(\theta) & \text{dBi} \quad 8.68^0 \le \varphi \le 54.81^0 \\ -42.3 & \text{dBi} \quad 54.81^0 \le \varphi \le 90^0 \end{cases} \qquad \text{Equation (3.15)}$$

The antenna radiation pattern for 2^0 given by:

$$G(\theta) = \begin{cases} 38.7 - 3(\theta/I^0)^2 & \text{dBi} \quad 0^0 \le \varphi \le 2.88^0 \\ 38.7 - 25 & \text{dBi} \quad 2.88^0 \le \varphi \le 3.46^0 \\ 46.16 - 60\log(\theta) & \text{dBi} \quad 3.46^0 \le \varphi \le 21.92^0 \\ -34.2 & \text{dBi} \quad 21.92^0 \le \varphi \le 90^0 \end{cases} \qquad \text{Equation (3.16)}$$

The effect of the antenna radiation pattern is related to the size of the cell and the loss for HAP with an altitude of $20\ Km$.

3.7. Intelligent Hand-off Requirements

For efficient and particular hand-off, it is necessary to understand and study many factors, parameters and techniques that are required to consider for taken hand-0ff decisions.

3.7.1. Spectrum Etiquettes using for Coexistence Enhancement

Spectrum etiquettes vary the transmitted power of the BS of newly activated system. These etiquettes are based on the Carrier Interference to Noise Ratio (CINR) and Interference to Noise Ratio (INR) at the receiver. INR and CINR are used to improve coexistence performance of HAP and terrestrial broadband systems that are intended for future applications. Applying spectrum etiquettes in HAP is to degraded power, since spectrum etiquettes control and limit the transmission power level from HAP [43].

Transmitted power is reduced in HAP to increase the CINR in order to maintain the modulation threshold level. The INR with -10 dB desired level forces the HAP system to transmit at very low power to the terrestrial for reducing the outage probability.

The general coexistence model is shown in Figure 3.11. It consists of HAP, a terrestrial system and users. This scenario assumes that HAP and terrestrial systems are represented as single system in the same coverage area and share same frequency. Here, different coexistence and deployment techniques for reducing the interference from HAP to terrestrial systems and for improving the cellular system performance are investigated [60, 61].

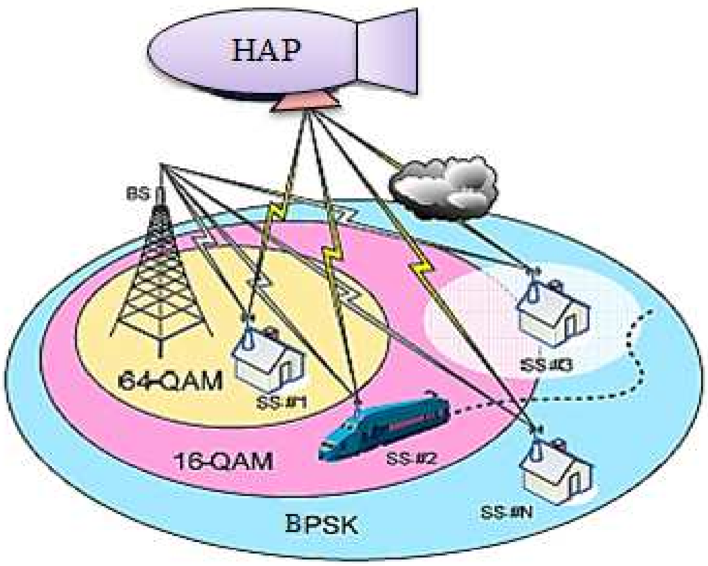

Figure 3.11 Spectrum Etiquettes for HAP and WiMAX

Particularly, it is concerned on investigating possible techniques for HAP to improve the coexistence performance because the concept of HAP has been recently introduced [61]. The most appropriate modulation levels ($64\ QAM, 16\ QAM, and\ BPSK$) which are determined to examine the performance of the coexistence in different environments as shown in Figure 3.11.

The INR is used to investigate coexistence performance which has $-10\ \mathrm{dB}$ threshold. Spectrum etiquettes are given by Equation (3.18) and Equation (3.17), respectively.

$$\mathrm{INR} = \mathrm{I/NF} = (\mathrm{P_H A_H(\emptyset) A_U(\theta) PL_T})/\mathrm{N_F} \qquad \text{Equation (3.18)}$$

$$\mathrm{CINR} = \mathrm{C/I + N} = \mathrm{P_H A_H(\varphi) A_U(\theta) PL_H / N_F + P_T A_T A_U(\theta) PL_T} \qquad \text{Equation (3.19)}$$

Where $\mathrm{N_F}$ is the thermal noise power, $\mathrm{P_H}$ is power transmitted of respected BS, $\mathrm{A_H(\emptyset)}$ is the transmit gain of BS antenna at an angle $\emptyset$ with respect to its boresight and the receive gain of the user antenna $\mathrm{A_U(\theta)}$ at an angle θ away from it bore sight are approximated by a cosine function raised to power roll-off factor n with a flat side lobe level. P_T is transmission power of WiMAX BS and A_T is the transmission gain of WiMAX BS. $A_H(\emptyset)$ and $A_U(\theta)$ are represented in Equation (3.20) and Equation (3.21), respectively [156].

$$A_H(\emptyset) = G_H\left(\max[\cos(\emptyset)^{n_H}, s_f]\right) \quad \text{Equation (3.20)}$$

$$A_U(\theta) = G_U\left(\max[\cos(\theta)^{n_U}, s_f]\right) \quad \text{Equation (3.21)}$$

Where G_H and G_U represent the boresight gain of the BS antenna and receive user antenna, and s_f represent a flat side lobe floor in dB. The linear path loss value PL_T is given by Equation (3.22) [157]:

$$PL_T = PL_m + \Delta PL_f + \Delta PL_h \quad \text{Equation (3.22)}$$

$$PL_m = A + 10\gamma \log_{10}(d/d_0) + s \quad \text{Equation (3.23)}$$

$$A = 20\log_{10}(4\pi d_0/\lambda) \quad \text{Equation (3.24)}$$

Where PL_m is the median path loss in dB and s represents the shadowing effects. The typical value of standard deviation for s is between 8.2 and 10.6 dB, depending on the tree density type. ΔPL_f is the frequency correction in dB given by Equation (3.25):

$$\Delta PL_f = 6\log(f/2000) \quad \text{Equation (3.25)}$$

Where f is frequency in MHz, PL_T Covers three common terrain categories described as category A, B and C [157].

The acceptable Level of INR is the main parameter utilized to evaluate the system performance. Accordingly, it is the reference to reduce the interference level from HAP to WiMAX. The HAP is the new technology that will occupy a frequency that is adjacent to the WiMAX, and will cause interference to another system. Hence, the INR is calculated based on three steps [158]:

1. To calculate the interference from HAP into WiMAX.
2. To compute the noise level of WiMAX receiver.

3. To find the INR level of the receiver in order to extract the required transmit power from HAP.

3.7.2. Receive Signal Strength for Hand-off

Radio propagation is essential for emerging technologies with appropriate design deployment and management techniques for any wireless network. It sites specific and varies significantly depending on terrain, frequency of operation, velocity of mobile terminal, interface sources and other dynamic factor. Signal strength between BS and mobile must be greater than threshold value, to maintain signal quality at receiver. Simultaneously, signal strength must not be too stronger to create more Co-Channel Interference (CCI) with channel in another cell using same frequency.

The RSS depends on the path loss and the parameters of the transmitter and receiver. Quality of call establishment is based on RSS. Signal strength varies based on the environment and the intermediate losses. Basic propagation models indicate that average RSS power decreases logarithmically with distance. In free space, path loss defines how much strength of the signal is lost during propagation from transmitter to receiver.

When the user is moving far away from the center of HAP coverage, the signal strength will be weak. Therefore, the user requires for strength RSS to continue the requested hand-off call. Increasing the distance between user and BS leads to increase the probability of hand-off. Movement of user forward the edge of BS also leads to decrease RSS. Thus, the probability of dropping hand-off call increases. Thus, hand-off takes place otherwise connection lost. The probability of hand-off can be calculated by Equation (3.26).

$$Pr = (T_{init} + S_{avg})/(T_{init} + T_{\min})$$ Equation (3.26)

Where, T_{init} initial threshold point at which initial hand-off process starts to find out target BS and T_{min} is minimum threshold point at which execution phase of hand-off start and below this point as well as S_{avg} is the average of received signal.

3.7.3. Propagation Path Models

Path loss plays a vital role to decide the QoS for wireless communication. Also it is an unwanted introduction of energy tending to interfere with proper reception and reproduction of the signal during its journey from transmitter to receiver. It causes a poor signal strength at the receiver side [159]. Therefore, the receiver is not able to detect the original signal.

Propagation models predict the mean RSS for both transmitter and receiver through separation distances. The variability of the signal strength in a particular location is useful to predict the radio coverage area of a transmitter, and characterize signal strength over large separation distance between transmitter and receiver. Propagation models can be broadly categorized into three types; empirical, deterministic and stochastic. Empirical models are based on observations and measurements alone. These models are mainly used to predict the path loss. The deterministic models make use of the laws governing electromagnetic wave propagation to determine the received signal power at a particular location. Stochastic models, on the other hand, model the environment as a series of random variables. We focused on the use of Hata model.

The basic characterization of the propagation of a wireless channel can be described as a large-scale and a small-scale fading. Path loss in wireless communication is diverse on frequency and distance. Hata model is available to predict the propagation loss. Hata model is used for empirical path loss [dB].

$$PL1_{hata}(dB) = A + B \log(d1) \quad \text{Equation (3.27)}$$

Where, d is distance in Km, A is fixed loss depends on frequency f in MHz and it is given by:

$$A = 69.55 + 26.16\log(\mathrm{f}) - 13.82\log(h_b) - a(h_m) \quad \text{Equation (3.28)}$$

$$B = 44.9 - 6.55\log(h_b) \quad \text{Equation (3.29)}$$

Where, $\mathrm{h_b}$ is height of BS antenna in m. $\mathrm{h_m}$ is height of mobile station antenna in meters. $a(h_m)$ is correlation factor in dBm and is given by:

$$a(h_m) = [1.1\log(f) - 0.7]h_m - [1.56\log(f) - 0.8] \quad \text{Equation (3.30)}$$

The path loss from BS B located at the distance of d2 from the mobile unit is given by:

$$PL1_{hata}(dB) = A + B \log(d2) \quad \text{Equation (3.31)}$$

3.7.4. Traffic Intensity

Traffic intensity is the average number of calls simultaneously in progress during a particular period of time. It measured in units of Erlangs. Thus 1 Erlang equals $1 * 3600$ call seconds. There are two type of traffic which either infinite or finite. Infinite traffic implies number of call arrivals, each with a small holding time. On other hand ,when the number of sources offering traffic to group of trunks or circuits is comparatively small in comparison to the number of circuits, this call finite traffic.

$$I = N_c\, t/T \quad \text{Equation (3.32)}$$

Where, I is traffic intensity, T is duration of monitoring period is average holding time. N_c is total number of calls in monitoring period.

3.7.5. Time Advance Technique

Time advance (TA) technique is used in the GSM system and is applied for mobile positioning. The mobile locations mean to check if mobiles are in an obstacle position or in the boundary of cell. Positioning of Ms is divided in to two categories: network based and handset based positioning [113].

One of handset based technique called the time advance [160] is applied in this system to determine where the Ms is. Measurement of TA can be used to calculate the distance between BS and the Ms. TA information is the propagation time between the Ms and BS, by checking the position of the training sequence transmitted from the Ms on uplink, the BS can calculate the TA value and send it back to the Ms in the downlink. Also, Zhang et al. (2012) and Xiong et al. (2012) Predicting of mobile user locations also has been investigated by mobile calls and exploiting collective behavioral patterns and, respectively [161, 162].

In this system, the total bit rate is set to be $R_b = 991\ K\ bits/Sec$. Thus, the distance that the wave can propagate in one bit duration is $d_b = (3x10^8)/2XR_b\ m$. The distance per bit of TA is then $d_b = 151\, m$. The BS-Ms distance can be measure as [113]:

$$d(TA) = TA\, X d_b \qquad \text{Equation (3.33)}$$

Where TA is rounded to the nearest of $(P/151)$. The position expression of the training sequence P can be found by $P = V\Delta(t)$ depending on the mobile velocity V and a time interval of measurement $\Delta(t)$.

Figure 3.12 shows the Rx delay and Tx delay that are used to find allocation. In the proposed hand-off method, we need to know the mobile locations (d) to check if the mobiles are in an obstacle position or at boundary of cell.

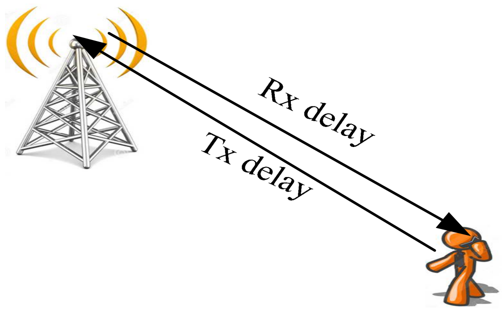

Figure 3.12 Time Advance and User Allocation

3.7.6. The MUSIC Technique

Multi Signal Classification (MUSIC) technique in the antenna array provides us an estimate of user direction consider the received signals impinging on L uniform linear antennas which consist of the (M< L) source signals corrupted by noise in the form of [7]:

$$x(t) = \sum_{m=1}^{M} a(\theta_m)S_m(t) + \eta(t) = A(\vartheta)S(t) + \eta(t) \qquad \text{Equation (3.34)}$$

Where $A(\vartheta) = a(\theta_1), \ldots \ldots, a(\theta_M)]$ is an LXM steering matrix whose column is the steering vector $a(\theta_m)$.

$$a(\theta_m) = \left[1 e^{-j2\pi\frac{d}{\lambda}\sin\theta_m} \ldots\ldots\ldots\ldots\ldots e^{-j(l-1)2\pi\frac{d}{\lambda}\sin\theta_m}\right]^T \qquad \text{Equation (3.35)}$$

Steering vector $a(\theta_M)$ of the signal $S_m(t)$ having an unknown angle of arrival θ_m. Where d/λ is the ratio of inter-element space of array to the signal wavelength. $\vartheta = [\theta_1, \ldots\ldots\ldots, \theta_M]$ is an angle of arrival vector of the M-source signal S(t)= $[S_1(t), \ldots\ldots, S_M(t)]^T$. The noise vector $\eta(t) = [\eta_1(t), \ldots\ldots, \eta_L(t)]^T$ is temporally and spatially white correlated [113].

The correlation matrix R of the array signal output can be written as:

$$R = E[X(t)X^H(t)] \qquad \text{Equation (3.36)}$$

An expression of R in term of eigenvalue and eigenvectors is:

$$R = U \wedge U^H \quad \text{Equation (3.37)}$$

Where each column of $U = [u_1, \ldots\ldots, u_L]_{LXL}$ constitutes eigvector and $\wedge$ is a diagonal matrix of eigenvalues λ_i corresponding to the eigenvector u_i. Decompose R into a signal subspace: $S = [u_1, \ldots\ldots, u_M]$ and noise subspace: $N = [u_{M+1}, \ldots\ldots, u_L]$. As a result of orthogonally of the steering vectors to the noise subspace, the MUSIC algorithm estimates the time of arrival vector of the signals by finding M peaks of the function:

$$P(\theta) = |a^H(\theta)N|^{-2} \quad \text{Equation (3.38)}$$

3.7.7. Distance

This algorithm connects the MS to the nearest BS. The relative distance measurement is obtained by comparing propagation delay times. This criterion allows handoff at the planned cell boundaries, giving better spectrum efficiency compared to the signal strength criterion [163]. However, it is difficult to plan cell boundaries in a microcellular system due to complex propagation characteristics. Thus, the advantage of distance criterion over signal strength criterion begins to disappear for smaller cells due to inaccuracies in distance measurements. A relative signal strength based algorithm gives less interference probability compared to a relative distance based algorithm.

3.8. Neural Network for Hand-off

ANN is one tool of artificial intelligence (AI) which utilized in this chapter for enhance the hand-off decision. ANN is a massively parallel distributed architecture which stores experimental knowledge. This knowledge is acquired by a learning process and is stored in the form of the ANN [164].

Recently, ANNs have been applied to many diverse problems. Adaptive parameters such as user speeds, RSS for pattern classification provide a multiple of criteria hand-off algorithm [165]. Neural network is trained to predict a user's transfer probabilities which represent the user movements [166]. A technique to recognize signal patterns of Ms using probabilistic neural network is introduced in Rayleigh fading channel [167].

The ANN consists of a number of neurons arranged in a particular fashion. The three basic elements of a neuron are the synaptic weights (or weights), the summing junction, and the activation function. Figure 3.13, describes the fundamental component of the ANN, an artificial neuron.

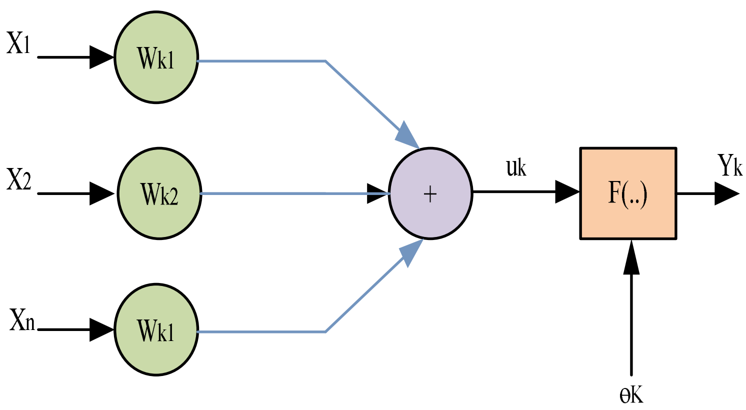

Figure 3.13 Model of Artificial neuron

Different activation functions include hard limit, linear, log-sig. threshold θ_k can be considered as one of the weight. The ANN consists of more than one neuron. The learning in ANN can be unsupervised or supervised. The output of a neuron k is given by:

$$u_k = \sum_{j=1}^{n} W_{kj} X_j \quad \text{Equation (3.39)}$$

$$Y_k = f(u_k - \theta_k) \quad \text{Equation (3.40)}$$

Where $X_j (j = 1,2, \ldots \ldots \ldots \ldots \ldots, p)$ are the input, W_{kj} are weights, θ_k is the threshold, $F(..)$ is the activate function, and Y_k is the output of neuron.

3.8.1. Radial Based Function Network

The Radial Based Function Network (RBFN) consists of three different layers, an input layer, a hidden layer and an output layer as shown in Figure 3.14. The input layer acts as an entry point for the input vector; no processing takes place in the input layer. The hidden layer consists of several Gaussian functions that constitute arbitrary basis functions (called radial basis functions); these basis functions expand the input pattern into the hidden layer space. This transformation from the input space to the hidden layer space is nonlinear due to nonlinear RBF.

Two distinct phases of learning in the RBFN are selection of enters of the RBF and determination of linear weights. Some of the methods for the selection of RBFN centers are random selection (based on the training patterns), unsupervised selection, and supervised selection. Some of the methods for linear weight determination are pseudo-inverse memory and LMS algorithm. These weight determination methods and a mapping between the hidden unit space and the output layer.

The output layer linearly combines the hidden layer responses to produce an output pattern. The rationale behind the working of the RBFN, a pattern-classification problem expressed in a high-dimensional space is more likely to be linearly separable than in a lower-dimensional space. The parameters of the RBFN weights (in the output layer) and the positions and spreads of the Gaussian functions. A complete learning procedure can be found in [164].

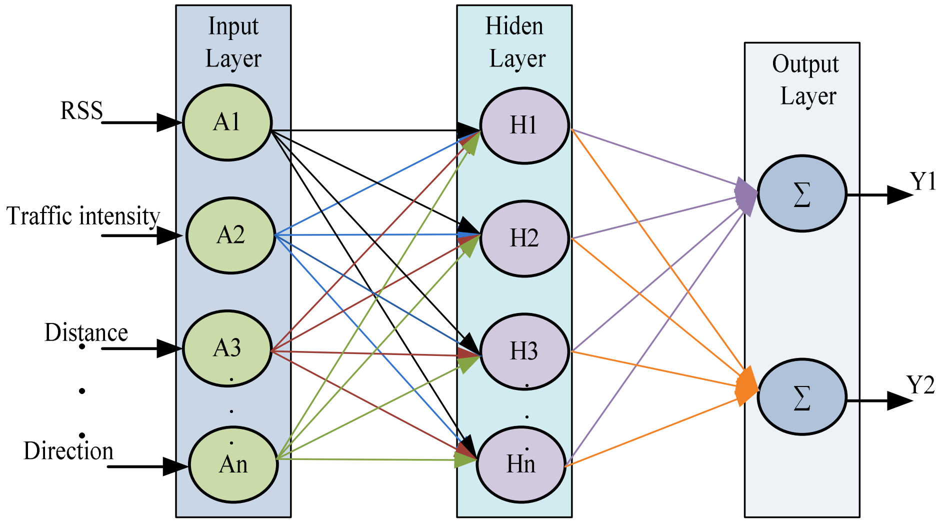

Figure 3.14 RBF Neural Network

Input nodes are RSS of MS and BS, Traffic intensity of MS and BS, direction, delay, channel availability, distance between MS and next BS. The output equals the summation of hidden layer. . The outputs decide whether the system needs a hand-off or not.

$$W_{k1}(n) = [W_k(n), \dots \dots \dots \dots, W_{k20}(n) \qquad \text{Equation (3.41)}$$

Initialize al the following, the center value $\mu_{ji}(0)$, the span value $\delta_j(0)$, weight vector $W_K(0)$, expect $W_{11}(0) = W_{21}(0) = 1$. Calculate the output of hidden layer and output layer are given respectively by:

$$Y_k = R[\sum_{J=I}^{M} W_{kj}(n)Z_J], k = 1,2; M = 20 \qquad \text{Equation (3.42)}$$

The error calculates by:

$$e_k = d_k - y_k \qquad \text{Equation (3.43)}$$

Where $d_k \epsilon \{0,1\}$ desired pattern and update the weight given by:

$$W_{kj}(n+1) = W_{kj}(n) - \tau_w e_k z_j \qquad \text{Equation (3.44)}$$

Where τ_w and τ_μ represent the learning rate of weight and center respectively, update the center and span momentum:

$$\mu_{ij}(n+1) = \mu_{ij}(n) + \tau_\mu \frac{z_j}{\delta_j}\left(x_i - \mu_{ji}(n)\right)\sum e_k w_{kj}(n) \qquad \text{Equation (3.45)}$$

$$\delta_j(n+1) = \delta_j(n) - \frac{2\tau_\delta\, z_j}{\delta_j(n)} \ln z_j \sum e_k w_{kj}(n) \qquad \text{Equation (3.46)}$$

Where τ_δ learning rate of span. Repeat the steps until the mean square error convergence less than small number.

3.9. The Proposed Technique for Intelligent Hand-off

Two BSs are considered in our work and the cell radius is assumed to be 1 Km under HAP coverage. Figure 3.15 is the flow chart illustrating the proposed hand-off algorithm. Signal strengths of the serving and target BS are monitored. When the RSS from the serving BS less than the threshold value and the RSS, then a hand-off is done to continue the call in progress. Otherwise, Hand-off decision will not be taken.

Therefore, HAP has been considered as a complementary layer for terrestrial mobile communication system, especially to provide connectivity in terrestrial mobile shadow zones. For superior decision making, the hand-off procedure has been augmented by using ANN and additional control parameters. We have proposed that the condition for taking a hand-off decision between a HAP link and a terrestrial link can be obtained by considering eight parameters viz.

i. RSS from terrestrial BS to the user (in his own cell),

$$-96 < RSS < -85\ dBm$$

ii. RSS from terrestrial BS to the user (in neighboring cell),

$$-96 < RSS < -85\ dBm$$

iii. RSS from HAP BS to the user (in respective HAP cell),

$$-96 < RSS < -85\ dBm$$

iv. Distance of the user from terrestrial BS (in his own cell) 1 Km.

v. Distance of the user from terrestrial BS (in neighboring cell) 1 Km .

vi. Direction of the user's movement by MUSIC

vii. Traffic intensity (availability of channel) in the neighboring cell,

$$0.65 < T < 0.75\ Erlangs/channels.$$

viii. Traffic intensity (availability of channel) in the HAP cell,

$$0.65 < T < 0.75\ Erlangs/channels.$$

We considered eight input $X = [X1, X2, \ldots\ldots.., X8]$. Also we have three outputs is to reduce number of iterations of learning process. The outputs of RBFN decide whether the system needs a hand-off or not. If $Y_1Y_2 = 00$, call will be dropped. If $Y_1Y_2 = 11$, hand-off performed to HAP. If $Y_1Y_2 = 10$, performed hand-off to next cell. If $Y_1Y_2 = 01$, no hand-off will be performed.

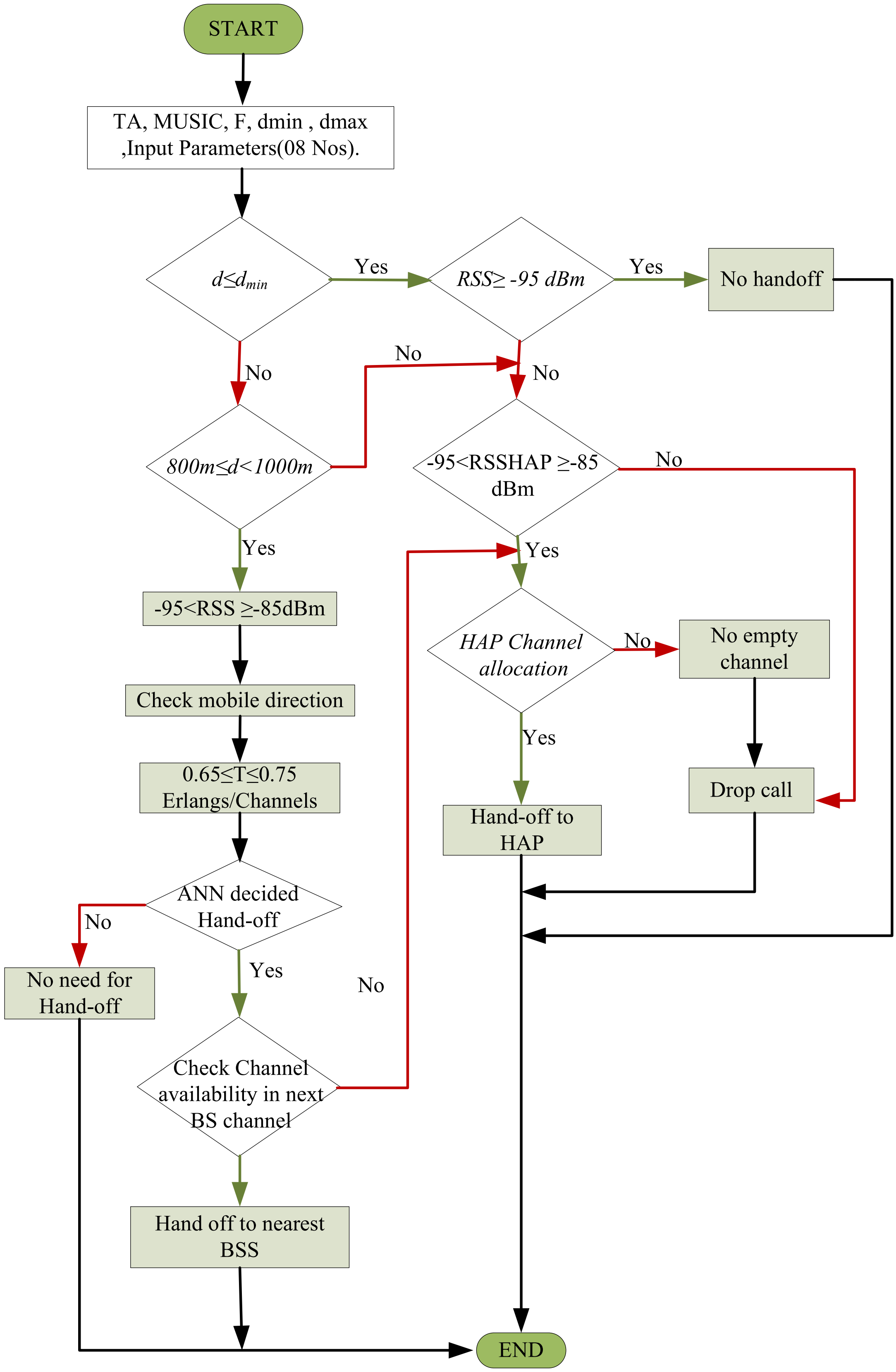

Figure 3.15 Hand-off Algorithm

3.10. Result and Discussion

The results and conclusions as drawn by us, in the light of above exploration are discussed as below:

3.10.1. Conclusion – I : Coexistence Performance

Coexistence is suitable with help of vary the modulation schemes of HAP from BPSK to 64-QAM modulation scheme. Therefore, WiMAX and HAP can work effectively in coexistence coverage.

In this case, the power transmitted from the HAP is lower than power transmitted from the WiMAX as shown in Figure 3.16. Therefore, adjust WiMAX power is not required. The signal to noise ratio isn't changed. This occurred because of using BPSK modulation on HAP due to which the INR is lower than threshold Figure 3.16 shows the INR decrease when the user is far away from HAP. In this case, the transmit power from HAP is higher than transmit power from terrestrial WiMAX as shown in Figure 3.17. Therefore, the INR is above of the threshold. The CINR is changed. Thus, transmit power of WiMAX BS is required to increase for provisioning of coexistence performance of these systems.

Figure 3.16 and Figure 3.17 are demonstrating that the WiMAX and HAP can work effectively in coexistence coverage. For various distances in 64 QAM, it is observed that when the carrier to noise ratio increased the distance between HAP and user also increased. INR decreased when the distance between HAP and WiMAX increased. When the user is far away from HAP, the interference decreases drastically because the user starts to go out of the HAP coverage and transmitted power of terrestrial system is getting higher.

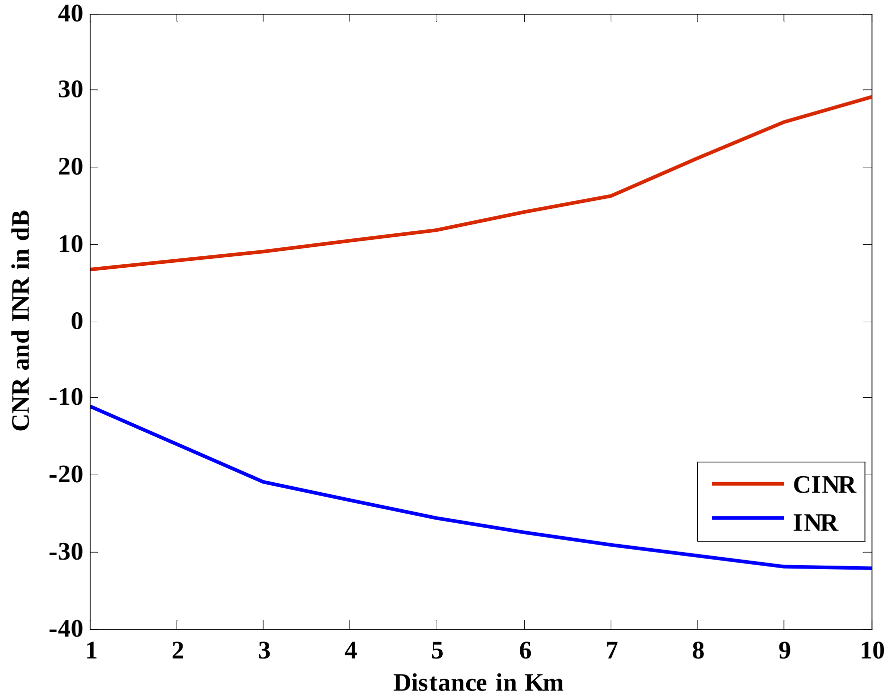

Figure 3.16 Spectrum Etiquettes in BPSK Modulation for Varies Distance

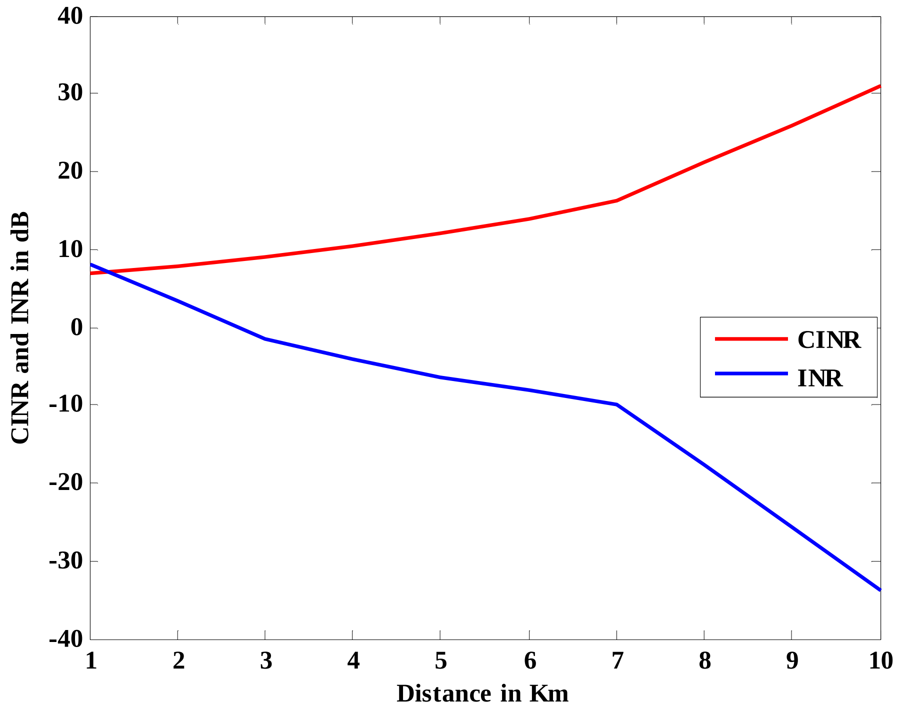

Figure 3.17 Spectrum Etiquettes in 64QAM Modulation for Varies Distance

3.10.2. Conclusion – II : Service Probability Performance

Single HAP with two antenna radiation patterns are considers as shown in Figure 3.18 and Figure 3.19. It is shown that, performance of service probability is represented as a percentage of the total number of users in the area which are served successfully via HAP. In case of the antenna pattern is 2^0 or 5^0, the best performance in terms of service probability is achieved with three tiers.

If the number of tier increases, the performance of service probability will improve, because the distance between cells is reduced. In case of using 2^0 antenna radiation pattern, the service probability performance reaches 97% for a load of 2500 users. On the other hand, by using the 5^0antenna radiation pattern, the service probability performance reaches 93% for a load of 2500 users. This means if the number of tier increases, the performance of service probability will improve much more. In case of antenna pattern 2^0 as shown in Figure 3.18, the performance of service probability is very high 97% in 2500 load. On the other hand, Figure 3.18 shows that, when the antenna pattern is 5^0, the performance of service probability is very high (95%) in 2500 load as shown in Figure 3.19. But the service probability in case of antenna pattern 2^0 is greater than antenna pattern 5^0.

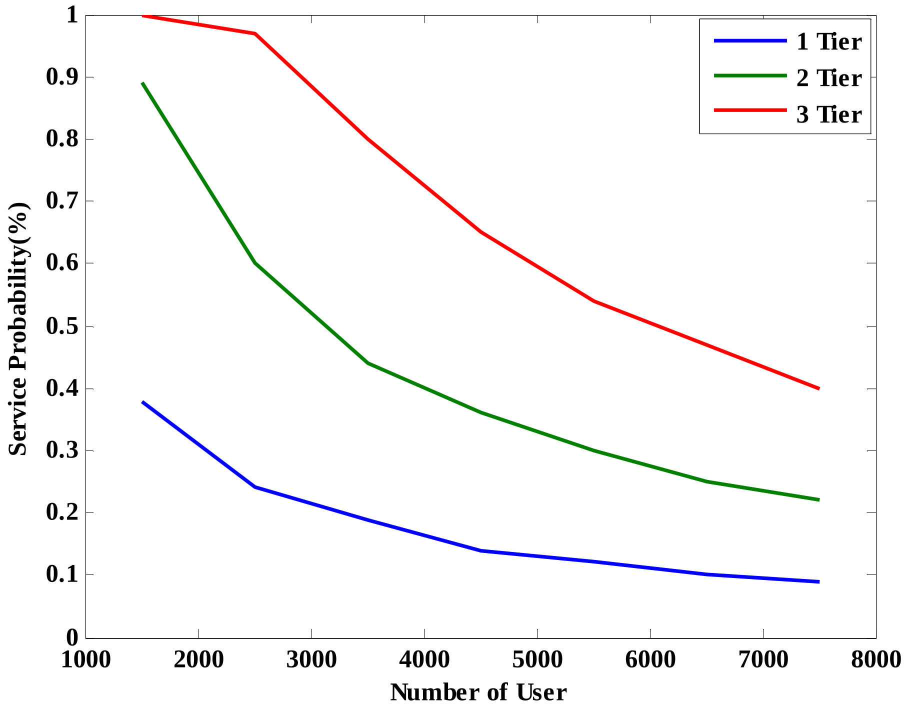

Figure 3.18 Service Probability in 2^0 Radiation Pattern

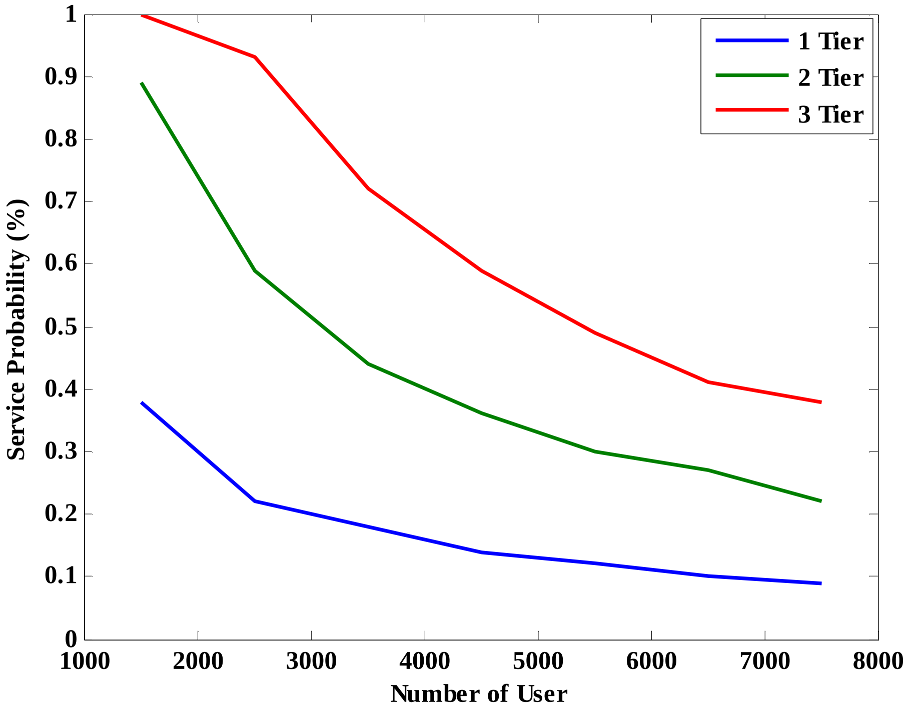

Figure 3.19 Service Probability in 5^0 Radiation Pattern

3.10.3. Conclusion – III : Receive Signal Strength

It is shown that, the hand-off using Hata model was at the largest distance. Thus, Hata model yields the postpones of the hand-off to the maximum distance should be adopted for sustain QoS. The RSS is calculated by using Hata model to determine which minimized the number of hand-offs as shown in Figure 3.20.

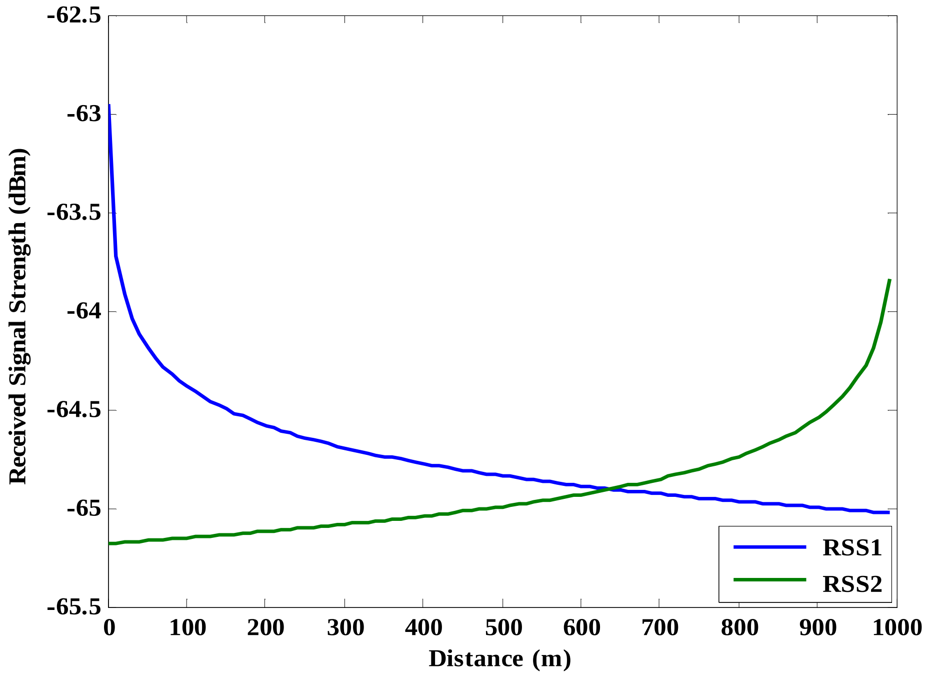

Figure 3.20 Receive Signal Strength Using Hata Model

3.10.4. Conclusion – IV : An Intelligent Hand-off by Applied ANN

The hand-off decision is illustrated in Figure 3.21 and Figure 3.22, using the RBFN. In Figure 3.21, the hand-off success rate remains between 0.199 to 0.183 when the mean arrive time rate changes from 3 to 4.6 min, respectively. On the other hand, the hand-off success rate stays between 0.21 to 0.25 even when the traffic intensity is varied between $0.65 < T < 0.75$ Erlangs/Channel. Further, by considering different traffic intensities and different mean arrival times, we have shown that the hand-off rate consistently exhibits lower values only. The results show that our proposed algorithm yields fewer hand-off and delivers more quality while taking hand-off decisions. The results show significant reduction in the rate of unnecessary handoff.

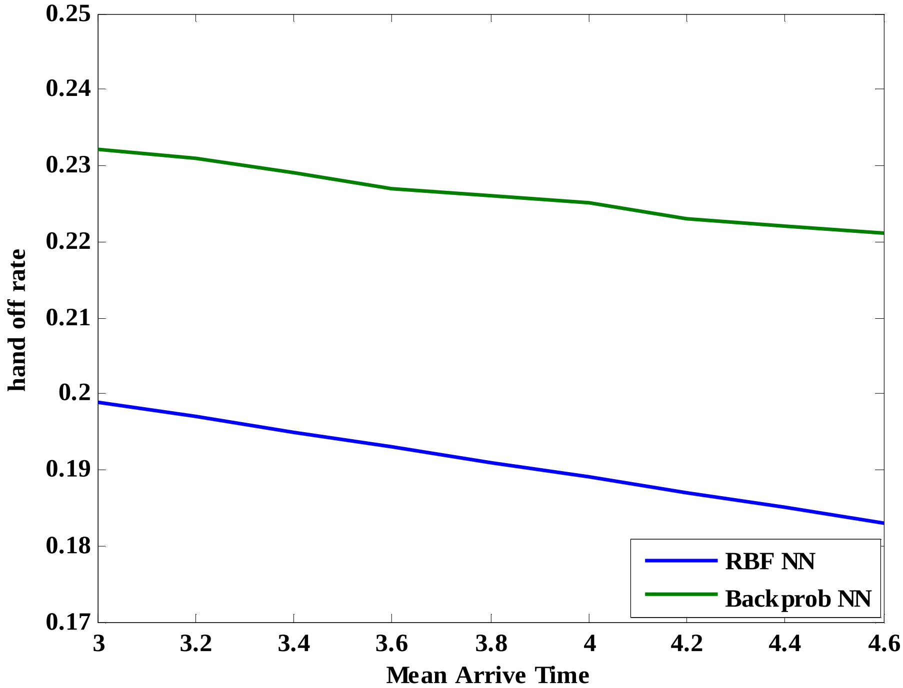

Figure 3.21 Hand-off Rate Versus Mean Arrival Time

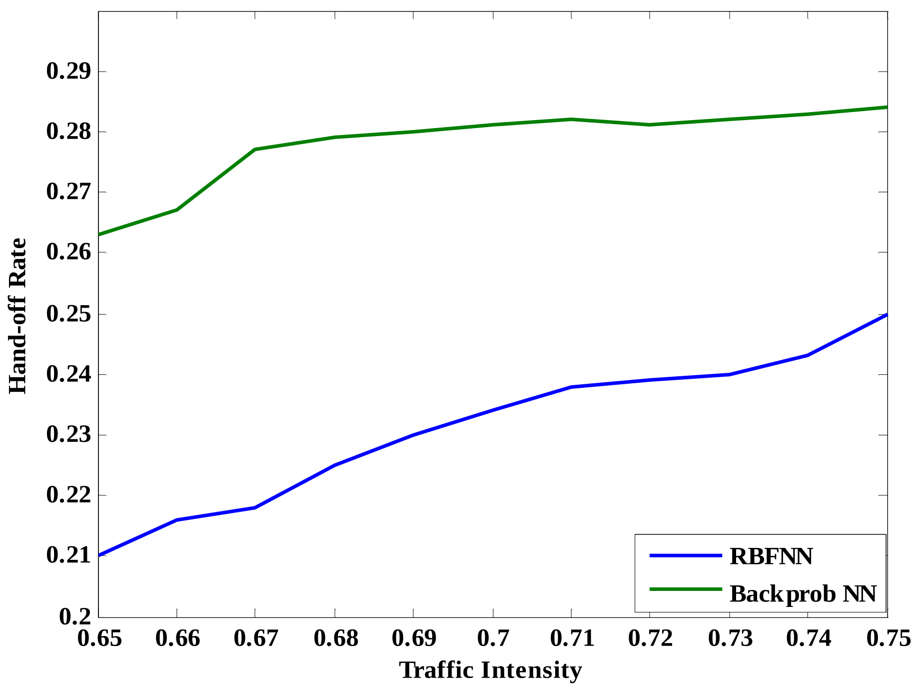

Figure 3.22 Hand-off Rate Versus Traffic Intensity

3.11. Conclusions

We have shown the coexistence performance of HAP and WiMAX. The result shows that the transmit power from HAP is lower than transmit power from that of the terrestrial, typically when BPSK modulation is used. On the other hand, spectrum etiquettes are required to adjust power because the transmitted power from HAP is more, in case of 64 QAM. Therefore, when the power of WiMAX should also be increased to reduce the INR. Therefore, by following the spectrum etiquettes, HAP can coexist with WiMAX and enhanced QoS can be maintained.

It has also been shown that the use of narrow beams deliver better performance although such use will reduce the cell size. Therefore, it is advised that additional tire should be added. If the number of tiers is increased, the performance of service probability will increase because the distance between cells is reduced and better QoS is delivered.

It has also been shown that the use of a high performance hand-off algorithm can achieve many of the desirable features by making appropriate trade-offs in making hand-off decisions. HAP system can provide services to the users staying at the corner of cells or at terrestrial coverage area which is influenced by shadowing. Effective hand-off algorithm is done based on RBFN for the coexisting scenario of HAP and terrestrial systems (one or even more than one). Thus many parameters have been taken from HAP side and terrestrial system side. Therefore, decision making by using ANN is highly adaptive and optimal. It is shown that, the hand-off rate improves when traffic intensity increases. As well as hand-off rate maintain low value when mean arrival time increase.