Chapter Four

Simulation Tools and Results

4. Simulation Tools and Results

4.1 Introduction

In this chapter, a program was designed using MATLAB to calculate the parameters of the vertical handover decision making in heterogeneous networks such as RSS, number of handovers, probability of handover and the QoS of calls.

4.2 Simulation Environment

Matrix laboratory is a programming language for technical computing; it is used for a wide variety of scientific and engineering calculations, especially for automatic control and signal processing. MATLAB is also noted for its extensive graphics capabilities. The system model designed using MATLAB language.

4.2.1 System Parameters

To move seamlessly from one network to another, the Received Signal Strength (RSS) was used as criteria in choosing the network with the highest signal strength. To maintain the Gross QoS, Received Signal must be strong enough at receiver side in order to have sustained on-going connection. The signal strength weakens as the mobile user moves farther from the serving node and conversely it gets stronger as the user moves near to the serving node.

For cellular network, the propagation characteristics for Macro cells are quite intricate as it gets affected by reflection from ground, vegetation, high-rise buildings and moving vehicles.

The received signal strength for cellular network is expressed in dBm as:

$$\mathbf{P_{cellular} = P_{Trans} + G_{Trans} - P_{Loss} - C} \qquad \textbf{(4.1)}$$

Where;

$P_{cellular}$ is cellular networks signal strength in dBm, P_{Trans} is transmitted power in dBm, G_{Trans} is gain of transmitting antenna gain in dB, P_{Loss} is total path loss in dB and C is connector and cable loss in dB.

To calculate the path loss, Okumura–Hata propagation model was used. A radio propagation model is a mathematical formulation for the characterization of radio wave propagation as a function of frequency, distance and other conditions. For Okumura–Hata model there are three models: rural, Suburban, urban, as shown in Figure 4.1.

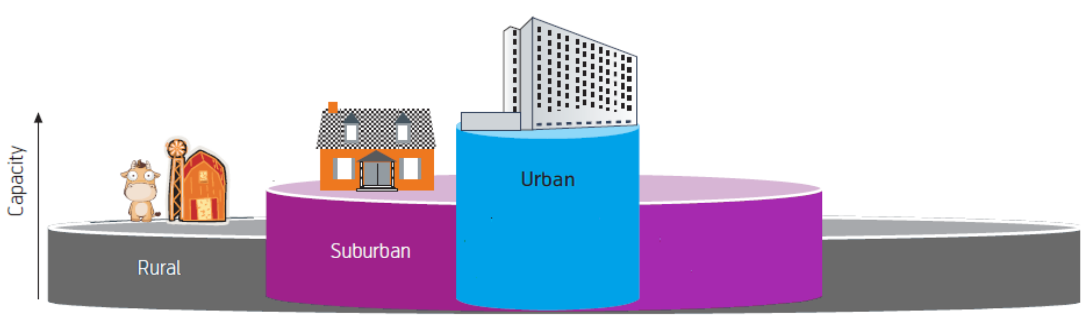


Figure 4.1: Okumura–Hata Model

Where:

- Urban: is "a Built-up city or large town crowded with large buildings and two-or more-storied houses, or in a larger village closely interspersed with houses and thickly-grown tall trees". Urban areas are sub classified as "Large city" or "Small city" for the purposes of correcting for mobile antenna heights.

- Suburban: is "a Village or highway scattered with trees and houses - the area having some obstacles near the mobile radio car, but still not very congested".

- Open or rural: is "No obstacles like tall trees or buildings in the propagation path and a plot of land which is cleared of anything 300 to 400m ahead.

Okumura-Hata model [19] takes urban areas as a reference and applies correction factors to calculate Path Loss values. The path loss is calculated using equation (4.2).

$$L_{hata}=69.55+26.16*\log fc-13.82\log hb-a(hm)+[44.9-6.55\log hb]*\log d-K \quad (4.2)$$

where:

- L_{hata} is the Path Loss .
- fc is the frequency in MHz , (values between 150 MHz to 1500 MHz).

- hb is the height of the base station in meters, between 30 and 200m.

- hm is the mobile antenna height in meters , between 1 m and 10 m.

- d is Link transmission distance (cell radius) in km.
- a(hm) and K are correction factors for environmental characteristics as described in Table (4.1).

Table 4.1: Hata Model Correction Factors

<table>
<tr><th>Type of area</th><th>a(hm)</th><th>K</th></tr>
<tr><td>Open</td><td rowspan="3">[1.1log10(fMHz) – 0.7] –[1.56log10 (fMHz) – 0.8]</td><td>4.78[log10(fMHz)]^2- 18.33log10 (fMHz)+ 40.94</td></tr>
<tr><td>Suburban</td><td>2[log10(fMHz /28)]^2 +5.4</td></tr>
<tr><td>Small city</td><td>0</td></tr>
<tr><td>Large city</td><td>3.2[log10(11.75 hm)]^2- 4.97</td><td>0</td></tr>
</table>

For wireless local area network, the received signal strength is given by equation (4.3)

$$RSS = P_{tx} - PL_{ref} - 10*beta*\log(d/d_0) + \sigma \quad (4.3)$$

where:

P_{tx}= Transmitted power of the network AP in dBm

PL_{ref}= Path loss at the reference point in dB

Beta= Path loss exponent

d_0=Distance between the AP and a reference point (m)

d = Distance between base station (AP) and MT.

σ = Zero –mean Gaussian random variable

In this thesis the RSS of each MT (UE) is measured after every 1 second. The handover process is established when the RSS of the user in a network becomes low. The received signal strength is used with a hysteresis value of 3 dB to avoid the ping pong process. Table 4.2 shows the parameters used in the simulation to calculate the RSS.

Table 4.2: Simulation Parameters

Network parameters	**Symbol**	**Value**
Radius cell	R	150m,500m,1500m
AP transmit power	P_{tx}	21dBm
Gain of cellular BS	G_{BS}	5 dB
Gain of WLAN AP	G_{AP}	5 dB
Threshold level	th	-90dbm

Distance between the AP and the reference point	dr	1m
Frequency	fc	700MHz
Height of the base station	hb	40m
Path loss exponent	beta	3.5
Standard deviation of shadow fading	σ	4.3 dB

The simulation system assumed is depicted in Figure 4.2; there are s servers and no waiting room. Calls arrive in a Poisson process with rateλ, the service time of each call has an exponential distribution with mean(1/ μ). Calls that arrive when all servers are busy are blocked and lost, so it is called a loss system.

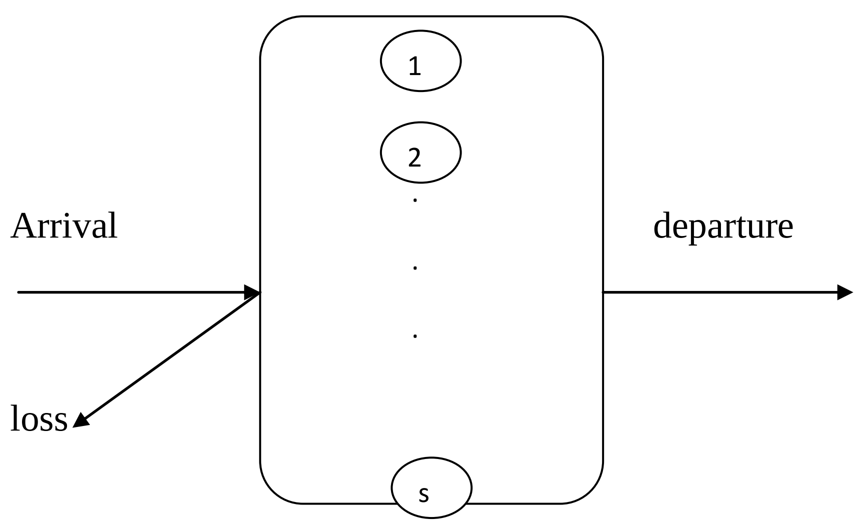


Figure 4.2 Loss System

The state of the system is defined by the number of calls present in the system, the state space is finite. The state follows a birth-and-death process, for which the state transition rate diagram is shown in Figure 4.3.

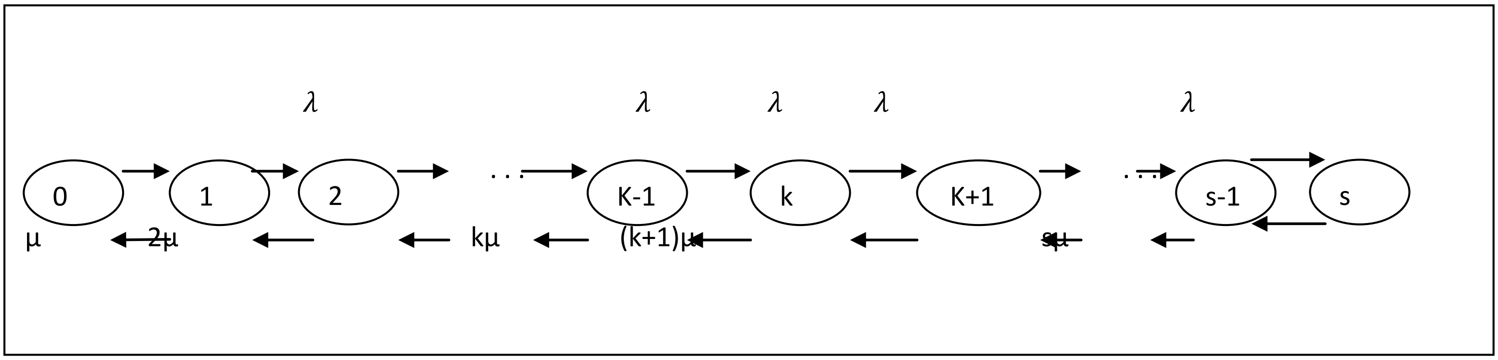


Figure 4.3: State Transition Rate Diagrams for the Simulated Loss System

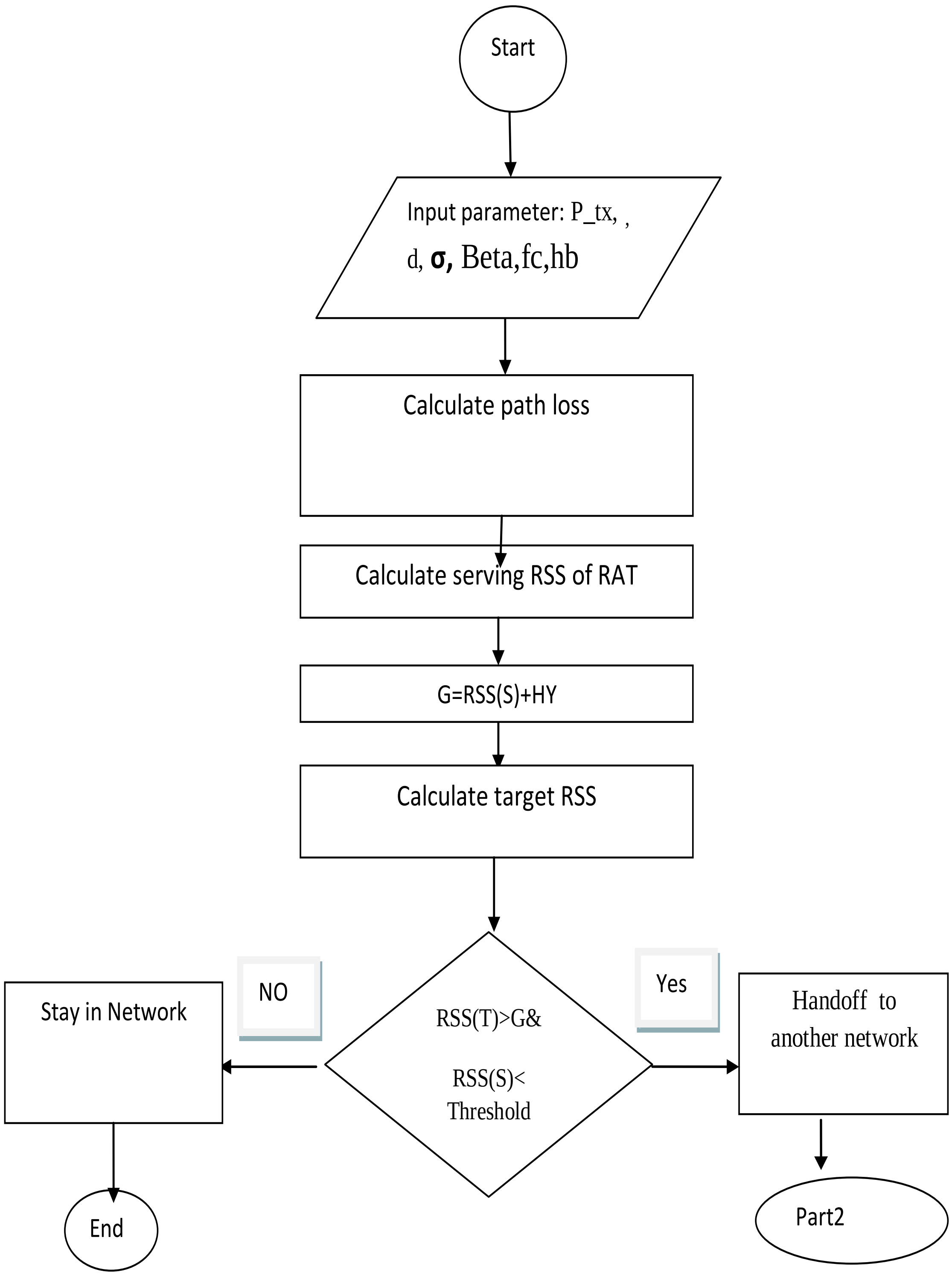
To admit a call from different heterogeneous networks with different technology, a block of basic bandwidth units (BBu) was allocated to it according to its class (voice, data, etc). The physical meaning of a basic bandwidth unit of radio resources (such as time slots , code sequence ,etc) is dependent on the specific technological implementation of radio interface. However, no matter which multiple access technology (FDMA, TDMA, CDMA, or OFDMA) is used, system capacity could be interpreted in terms of effective or equivalent bandwidth. Therefore, whenever in this thesis it is referred to bandwidth of a call, it is meant to be the number of BBu that is adequate for guaranteeing the desired QoS for this call.

It is assumed that the heterogeneous network supports 2 classes of calls. Each class is characterized by bandwidth requirement. Each class-i call requires a discrete bandwidth value, bi, where bi belongs to the set Bi = {bi} fori=1, 2.The requested bandwidth of an incoming class-*i*call is denoted by $b_{i,\text{req}}$, where $b_{i,\text{req}} \in$Bi. Let $m_{i,}$ denote the number of handoff class-*i*with $1 \leq c \leq m_i$. Let $b_{i,\text{assigned}c}$denote the total bandwidth assigned to call *c* of class-*i* where $b_{i,\text{assigned}c}$ $\in$Bi. If $b_{i,\text{req}} < b_{i,\text{assigned}c}$the call is admitted otherwise it is blocked.

4.3 Simulation Flow Chart

The flow chart scenario of the VHO is depicted in Figure 4.4.Depending on the movement of the Mobile Node (MN) from cellular to WLAN or vise versa, the RSS of the serving RAT is calculated. If the RSS of the serving RAT is less than a specified threshold value and the RSS of the target RAT is greater than the RSS of the serving RAT added to it a hysteresis value to avoid ping pong process, then a handover to the target station is performed. Otherwise, the MN remains in its current network.

When a handoff to the target network occurs its traffic is checked to detect its class, according to its class, it is directed to the corresponding partition. The call will be assigned to the partition if it has enough bandwidth, otherwise the call will be blocked.


Start
Input parameter: P_tx, ,
d, σ, Beta,fc,hb
Calculate path loss
Calculate serving RSS of RAT
G=RSS(S)+HY
Calculate target RSS
NO
Yes
Stay in Network
RSS(T)>G&
RSS(S)<
Threshold
Handoff to
another network
End
Part2

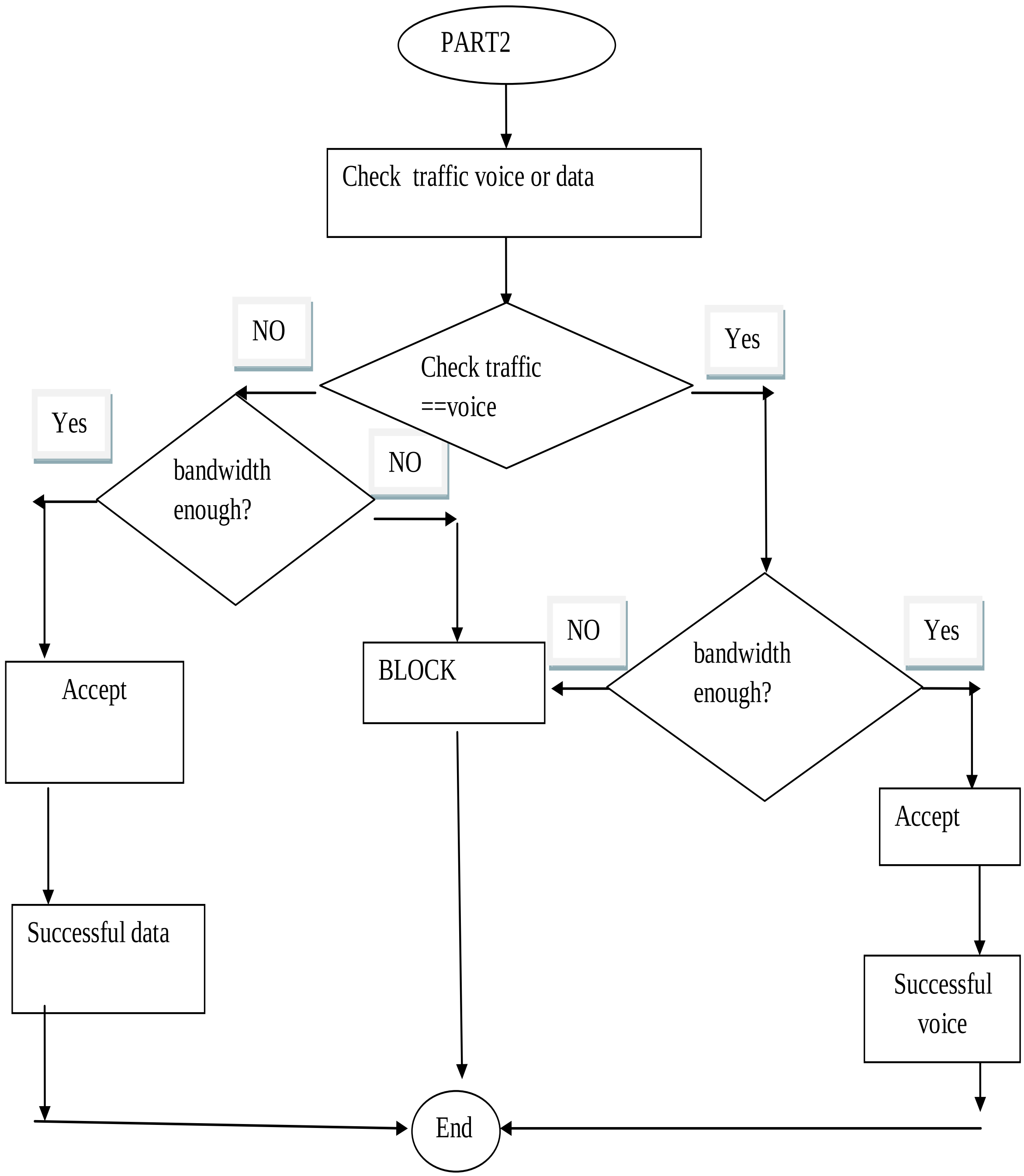


Figure 4.4: The Flow Chart of VHO

4.4 Results and Discussion

In this section, five different scenarios were simulated. Two types of call classes were considered; (class 1 call), voice for example and (class 2 call)which may represent a data call.

Scenario One: RSS Vs Distance of One User

In this case, the RSS of one user is calculated while varying the radius of the cell .Figure 4.5, 4.6 and 4.7 shows the relationship between the RSS and the distance of different cell radius. It was assumed that the user is moving towards the cell edge or far away from base station (AP). Figure 4.5 shows the RSS vs distance when the radius of the cell is 150 meter.

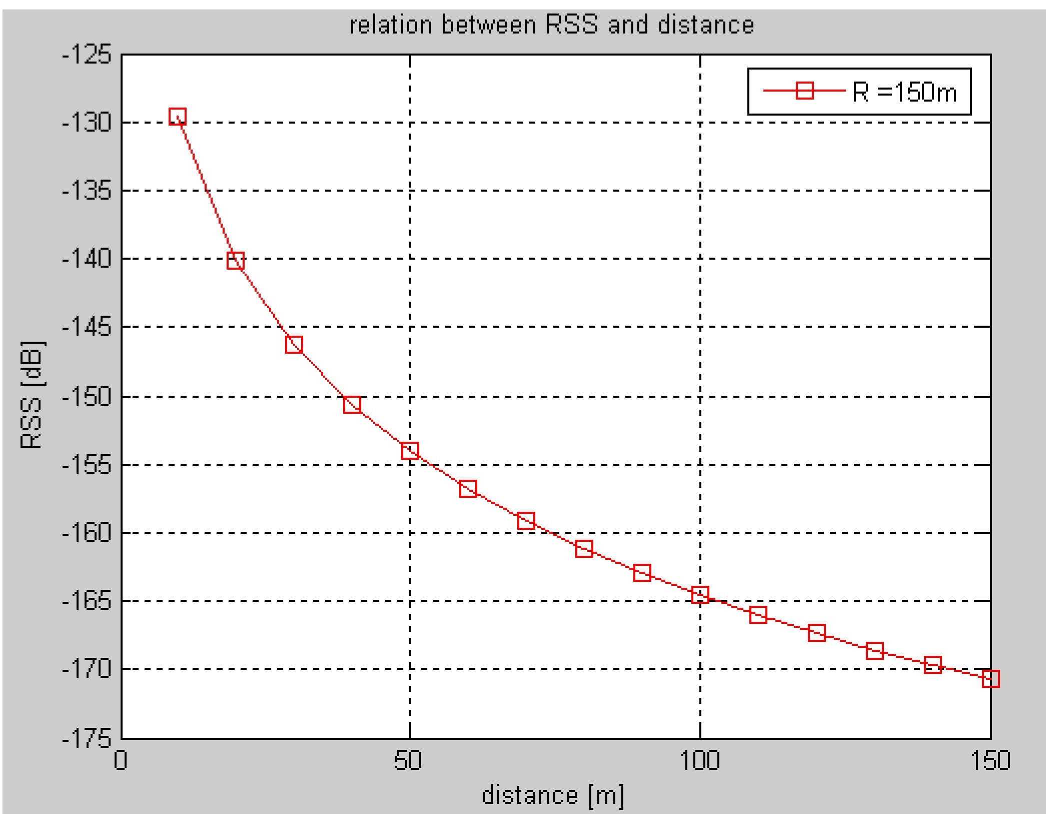


Figure 4.5: RSS Vs Distance with Radius 150m

The Figure4.5 shows that as the distance increases the RSS decreases.

Figure 4.6 shows the RSS vs distance when the radius of the cell is 500 meter.

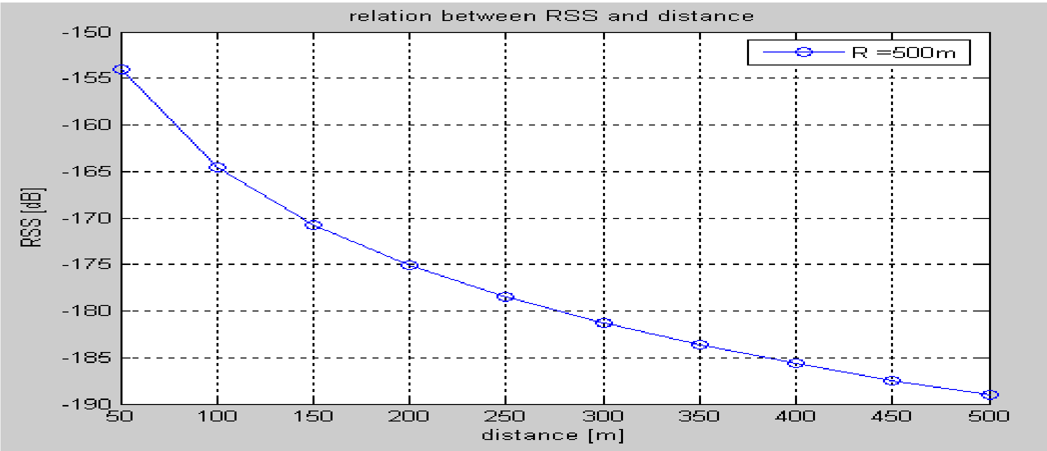


Figure 4.6:RSS Vs Distance with Radius 500m

The Figure 4.6 shows that as the distance increases the RSS decreases.

Figure 4.7 shows the RSS Vs distance when the radius of the cell is 1500 meter.

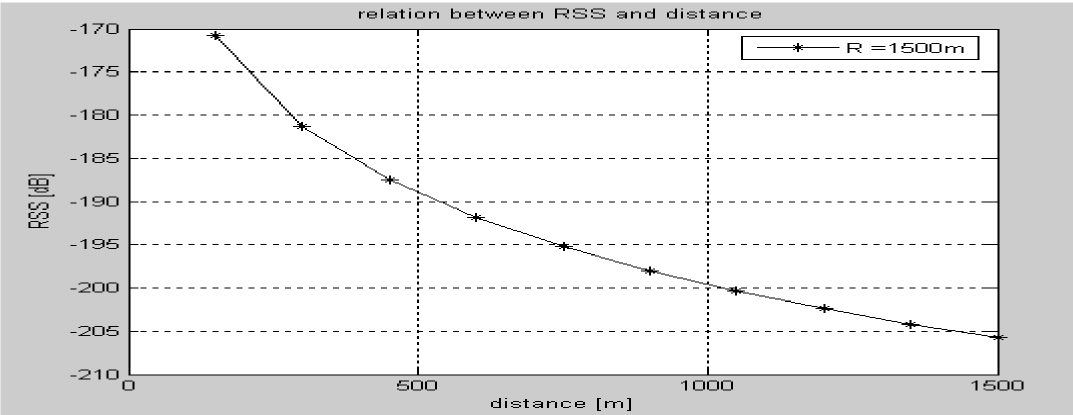


Figure 4.7**:**RSS Vs Distance with radius 1500m

The Figure 4.7 shows that as the distance increases the RSS decreases.

Figure 4.8 illustrates RSS with different cell radius for one user.

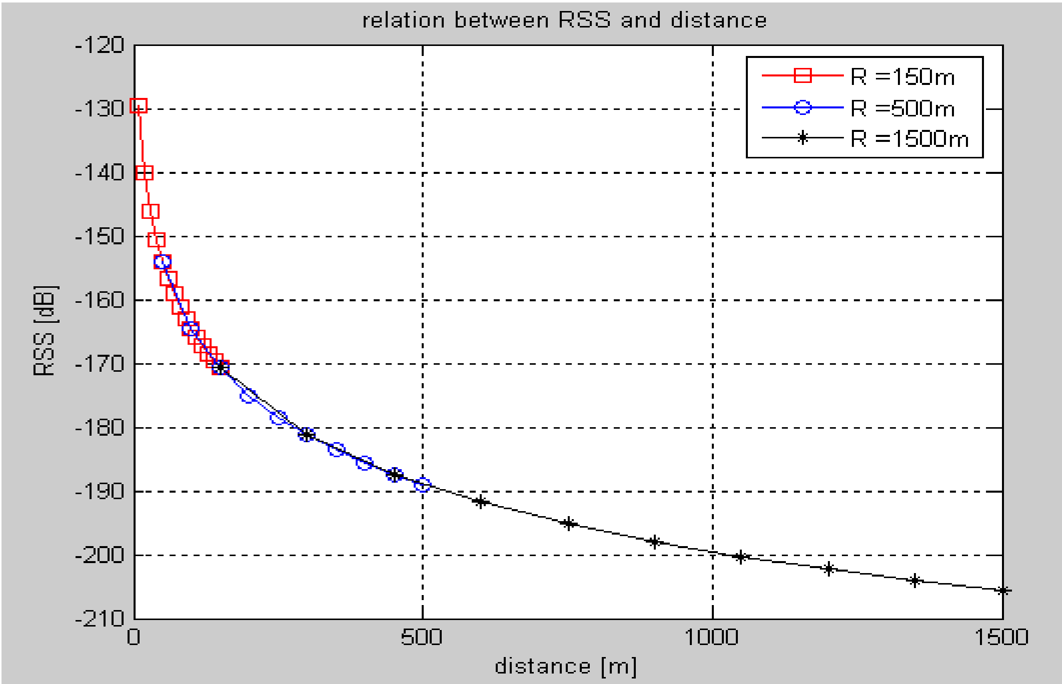


Figure 4.8:RSS Vs Distance with different radius of cell

From the Figure 4.8 it was noticed that as the cell radius increases the RSS of the user decreases.

Scenario Two: Handover Probability Vs Cell Radius

Figure 4.9 shows the relationship between the radius of the cell and the probability of handover.

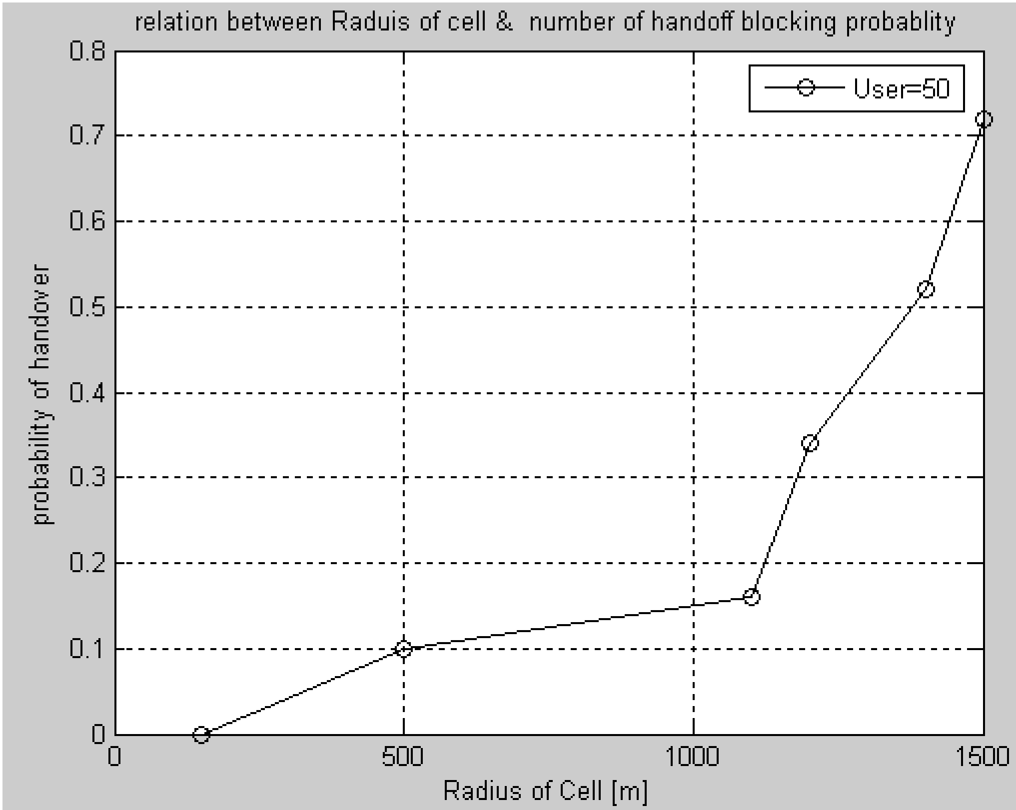


Figure 4.9: Radius of Cell Vs Probability of handover

From Figure 4.9 it was noticed that when the radius of cell increase the probability of handover increase.

Scenario Three: Varying Height of Base Station Vs Path Loss

In this case, the height of base station is varied with the path loss while having the frequency fixed. Figure 4.10 shows the relationship between the height of the base station and path loss.

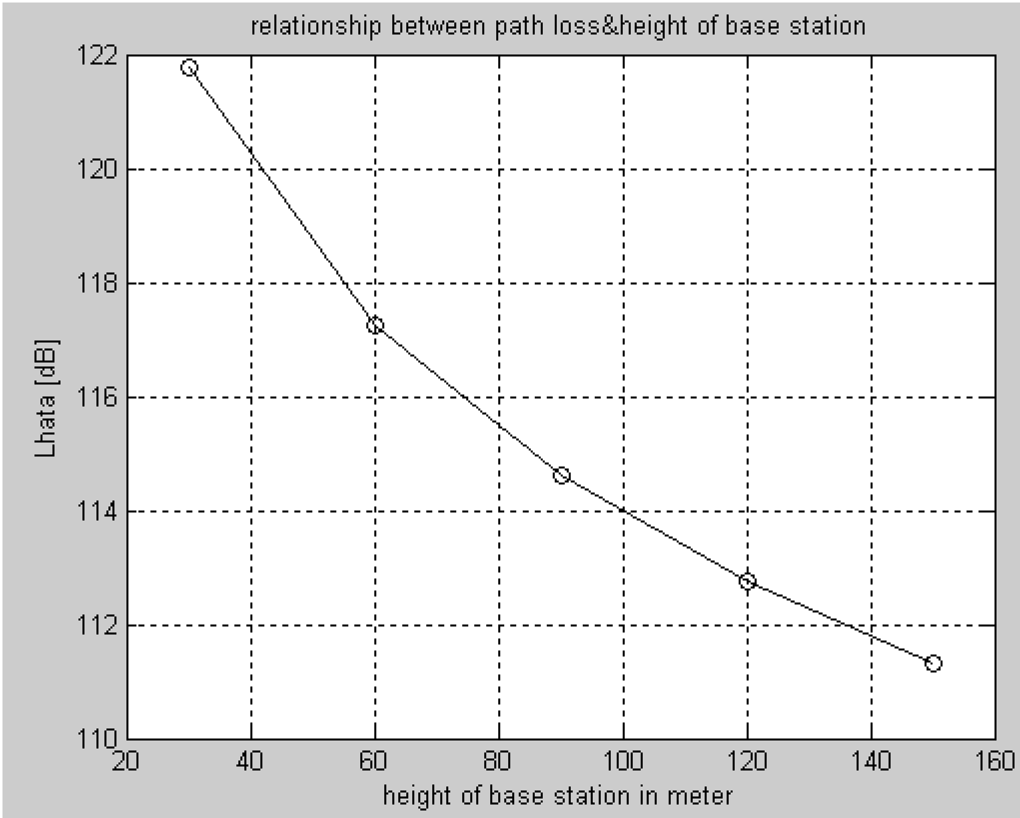


Figure 4.10: Height of Base Station Vs Path Loss

Figure 4.10 shows that as the height of the base station increases the path loss decreases resulting in a low RSS.

Scenario Four: Varying the Number of Channels

In this case study, the number of channels reserved for both calls class 1 and class 2were varied to test their effect on the blocking probability. In this simulation the total number of users randomly generated was 180. Depending on their RSS, 166 users had a handover process with 95 users of calls class 1 and 71 users of calls class 2. The total number of BBUs is 220 with 180BBUs reserved for calls class 1 and 40 BBUs reserved for calls class2. For calls class 1 different number of bbu were considered; 9, 7 and 3, with 9 representing the best QoS the user can obtain and 3 the worst. Table 4.3, 4.4 and 4.5 shows the different number of channels used for calls class 1 for different number of bbu.

Table 4.3: Parameters for calls class 1with 9 BBU

BBU for Calls Class 1	**Number of BBU for one call class1**	**Number of channel reserved**	**Blocking probability**
180	9	20	0.7894
160	9	17	0.8211
135	9	15	0.8421

Table 4.4: Parameters for calls class 1with 7 BBU

BBU for Calls Class 1	**Number of BBU for one call class1**	**Number of channel reserved**	**Blocking probability**
180	7	25	0.7368
160	7	22	0.7684
135	7	19	0.8000

Table 4.5: Parameters for calls class 1with 3 BBU

BBU for Calls Class 1	Number of BBU for one call class1	Number of channel reserved	Blocking probability
180	3	60	0.3684
160	3	53	0.4421
135	3	45	0.5263

Figure 4.11 illustrates class1 calls blocking probability for different BBUs reserved for one call.

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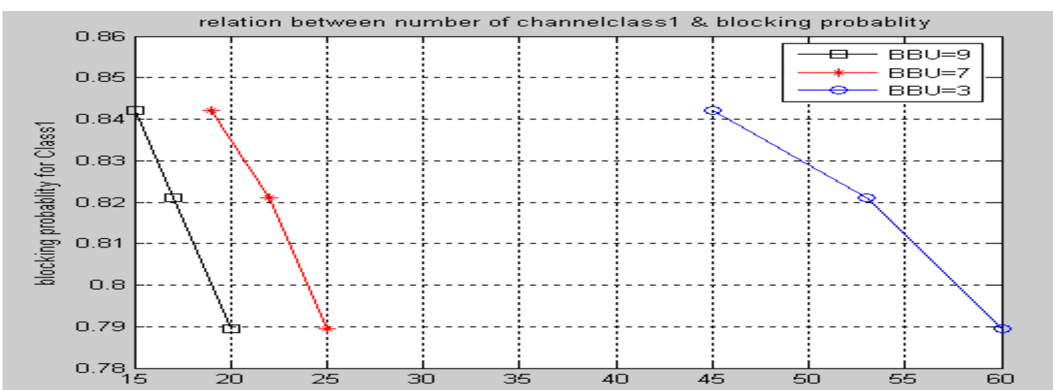

Figure 4.11: Number of Channel Vs Blocking Probability for calls class 1

From the Figure 4.11 it can be concluded that as the number of channels for calls class 1 increases the blocking probability decreases since more channels will be available to accommodate more users. The figure also shows that when providing a user with a high QoS, which is using 9bbu, for a single call, the number of channels available is less than when using a 3bbu and providing the user with a low QoS for a single call.

For calls class 2 different number of bbu were considered; 4, 2 and 1, with 4 representing the best QoS the user can obtain and 1 the worst. Table 4.6, 4.7 and 4.8 shows the different number of channels used for calls class 2 for different number of bbu.

Table 4.6: Parameters for calls class 2 with 4 BBU

BBU for Calls Class 2	**Number of BBU for a Call Class 2**	**Number of channel reserved**	**Blocking probability**
40	4	10	0.8592
20	4	5	0.9296
16	4	4	0.9434

Table 4.7: Parameters for calls class 2 with 2 BBU

BBU for Calls Class 2	Number of BBU for a Call Class 2	Number of channel reserved	Blocking probability
40	2	20	0.7183
20	2	10	0.8592
16	2	8	0.8873

Table 4.8: Parameters for calls class 2 with 1 BBU

BBU for Calls Class 2	Number of BBU for a Call Class 2	Number of channel reserved	Blocking probability
40	1	40	0.4366
20	1	20	0.7183
16	1	16	0.7746

Figure 4.12 illustrates calls class2 blocking probability for different BBUs reserved for one call .

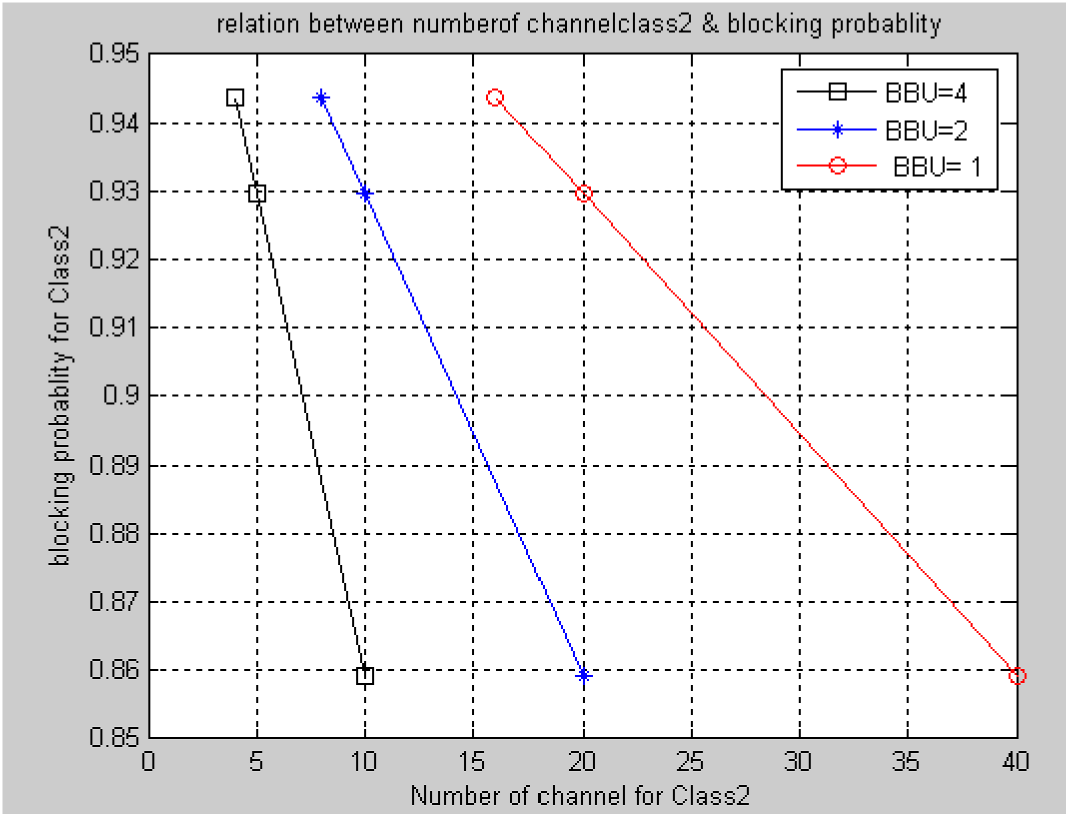

Figure 4.12: Number of Channel Vs Blocking Probability for calls class 2

From the Figure 4.12 it can be concluded that in order to decrease the blocking probability, the number of channels for calls class 2 must increase to accommodate more users. The figure also shows that by providing the user with a high QoS that is using 4bbu for a single call, the number of channels available is less than when using 1bbu and providing the user with a low QoS for a single call.

Figure 4.13 and Figure 4.14 illustrates the QoS for calls class 1 and calls class2 respectively, using different BBUs reserved for one call.

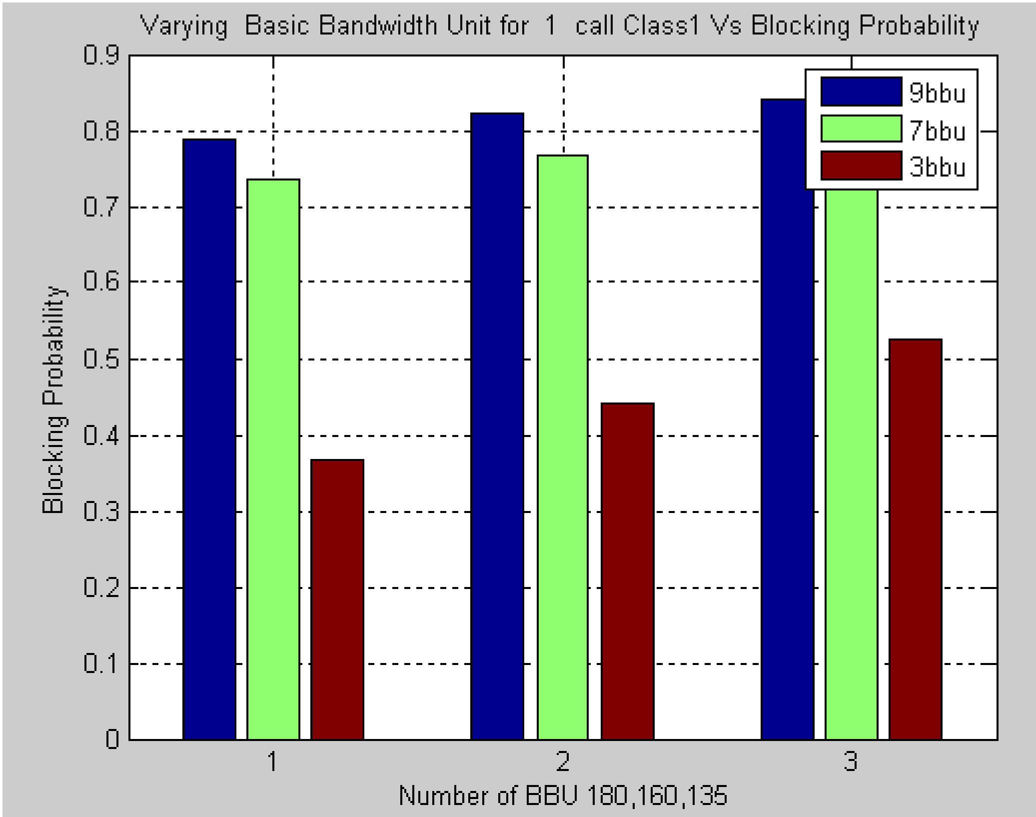

Figure 4.13**:**Blocking Probability Vs Total number of BBu for calls class 1

From Figure 4.13, it can be concluded that as the total number of bbu decreases the blocking probability increases. The basic bandwidth unit of 3 provides the lowest blocking probability which is what a service provider desires, but from the user point of view the QoS is poor. It can be concluded that the 7BBu provides both an acceptable blocking probability and a good QoS

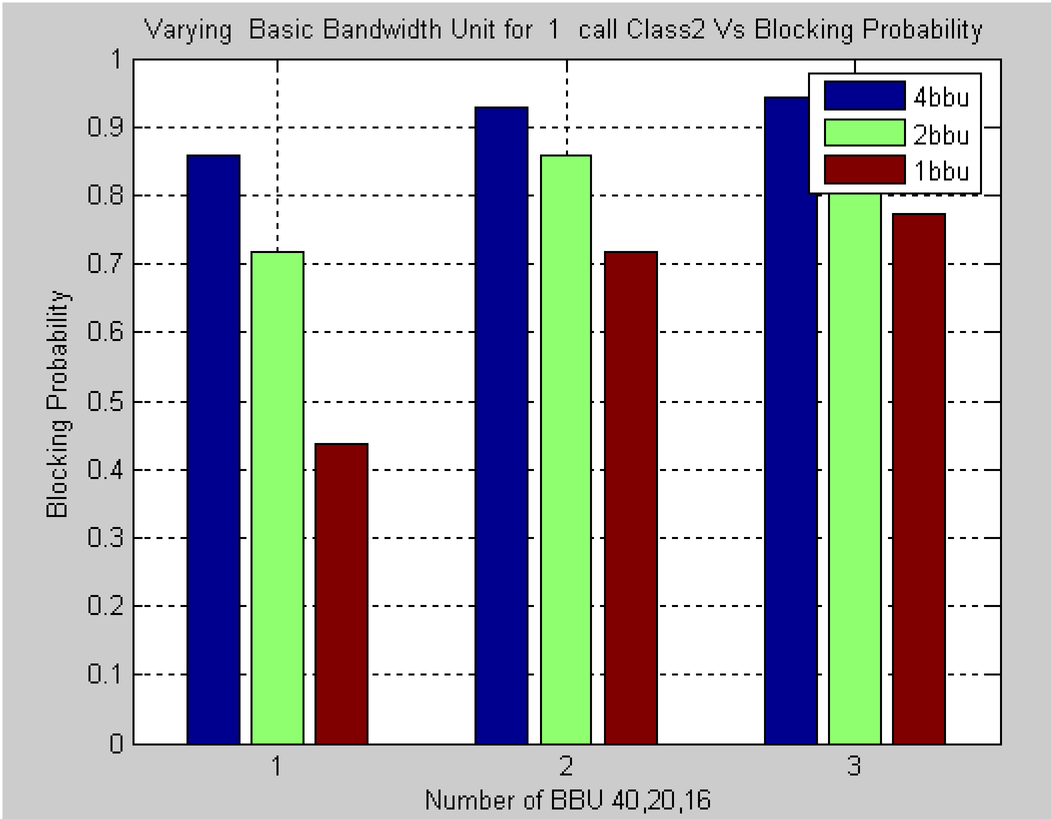

Figure 4.14**:** Blocking Probability Vs Total number of BBu for calls class 2

From Figure 4.14 .it can be concluded that as the total number of bbu decreases the blocking probability increases. The basic bandwidth unit of 1 provides the lowest blocking probability which is what a service provider desires, but from the user point of view the QoS is poor. It can be concluded that the 2BBu provides both an acceptable blocking probability and a good QoS

Scenario Five: Varying the Number of Handover Users

Table 4.9, 4.10 and 4.11 shows the different number of handover users for calls class 1 for different number of bbu. The number of channels reserved for calls class 1 was fixed in each case and the total number of bbu was set to 180.

Table 4.9: Parameters for Varied Number of Handover Users for calls class 1 with 9 BBU

Number of Handover Users	BBU for a Call Class 1	Number of channel reserved	Blocking probability
95	9	20	0.7894
105	9	20	0.8095
130	9	20	0.8462

Table 4.10: Parameters for Varied Number of Handover Users for calls class 1 with 7 BBU

Number of Handover Users	BBU for a Call Class 1	Number of channel reserved	Blocking probability
95	7	25	0.7368
105	7	25	0.7619
130	7	25	0.8077

Table 4.11: Parameters for Varied Number of Handover Users for calls class 1 with 3 BBU

Number of Handover Users	BBU for a Call Class 1	Number of channel reserved	Blocking probability
95	3	60	0.368
105	3	60	0.4286
130	3	60	0.5384

Figure 4.15 illustrates the blocking probability of calls class1 when varying the number of users.

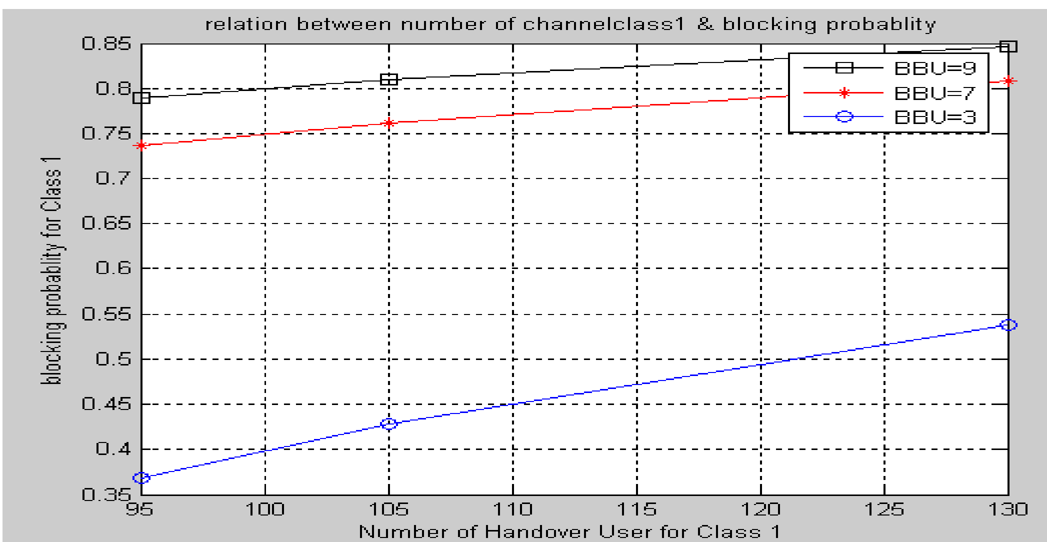

Figure 4.15**:**Number of Handover User Vs Blocking Probability for Calls Class1

From Figure 4.15, it can be concluded that as the number of handover users increase the blocking probability increases, since there will not be enough channels to accommodate the users. The figure also showed that using 3 bbu resulted in providing the lowest blocking probability which is good for the service provider point of view but in a low QoS for the users.

Table 4.12, 4.13and 4.14shows the different number of handover users for calls class 2 for different number of bbu. The number of channels reserved for calls class 2 was fixed in each case and the total number of bbuwas set to 40.

Table 4.12:Parameters for Varied Number of Handover Users for calls class 2 with 4BBU

Number of Handover Users	**BBU for one Call Class 1**	**Number of channel reserved**	**Blocking probability**
71	4	10	0.8592
96	4	10	0.8958
121	4	10	0.9174

Table 4.13:Parameters for Varied Number of Handover Users for calls class 2 with 2 BBU

Number of Handover Users	BBU for a Call Class 2	Number of channel reserved	Blocking probability
71	2	20	0.7183
96	2	20	0.7917
121	2	20	0.8347

Table 4.14:Parameters for Varied Number of Handover Users for calls class 2 with 1BBU

Number of Handover Users	BBU for a Call Class 2	Number of channel reserved	Blocking probability
71	1	40	0.4366
96	1	40	0.5833
121	1	40	0.6694

Figure 4.16 shows the blocking probability of calls class 2 using different reservation for one call.

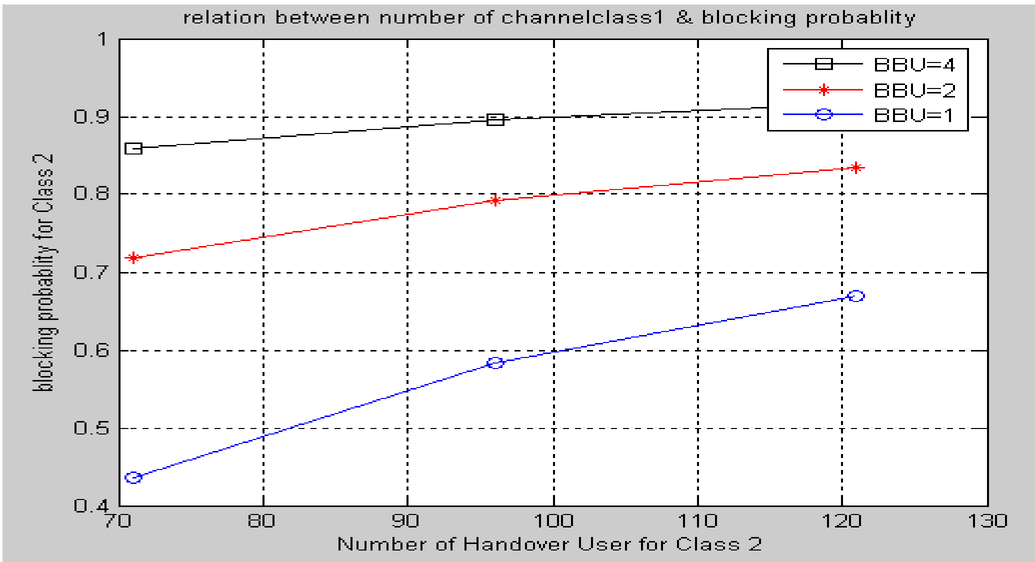

Figure 4.16Number of Handover Users Vs Blocking Probability for Calls Class 2

From Figure 4.16, it can be concluded that as the number of handover users increase the blocking probability increases, since there will not be enough channels to accommodate the users. The figure also showed that using 1 bbu resulted in providing the lowest blocking probability compared to the 2bbu and 4bbu, which is good for the service provider point of view, but it results in a low QoS for the users.