Chapter Four

Simulation and Results

4. Simulation and Results

4.1 Introduction

This chapter presents the methodology used for Call Admission Control using Bandwidth Reservation in LTE network. Both the static and the adaptive bandwidth reservation methods were used. The static bandwidth reservation method reserve a fixed amount of cell bandwidth for handoff calls, VoIP calls, and video calls. While the call admission control (CAC) based on the adaptive bandwidth reservations uses thresholds that are dynamically adjusted to avoid the waste of reserved bandwidth and maintain the QoS of already admitted connections and prioritize handoff call over new call and prioritize VoIP over Video type. The call requests are classified into new call and handoff call, and new calls are classified into voice over IP calls (VoIP) or video calls.

4.2 Simulation Environment

To evaluate the CAC algorithms, MATLAB R2013a software was used.

Two bandwidth reservation methods were simulated; the static and the adaptive bandwidth reservation methods. Figure 4.1 shows the static bandwidth reservation method.

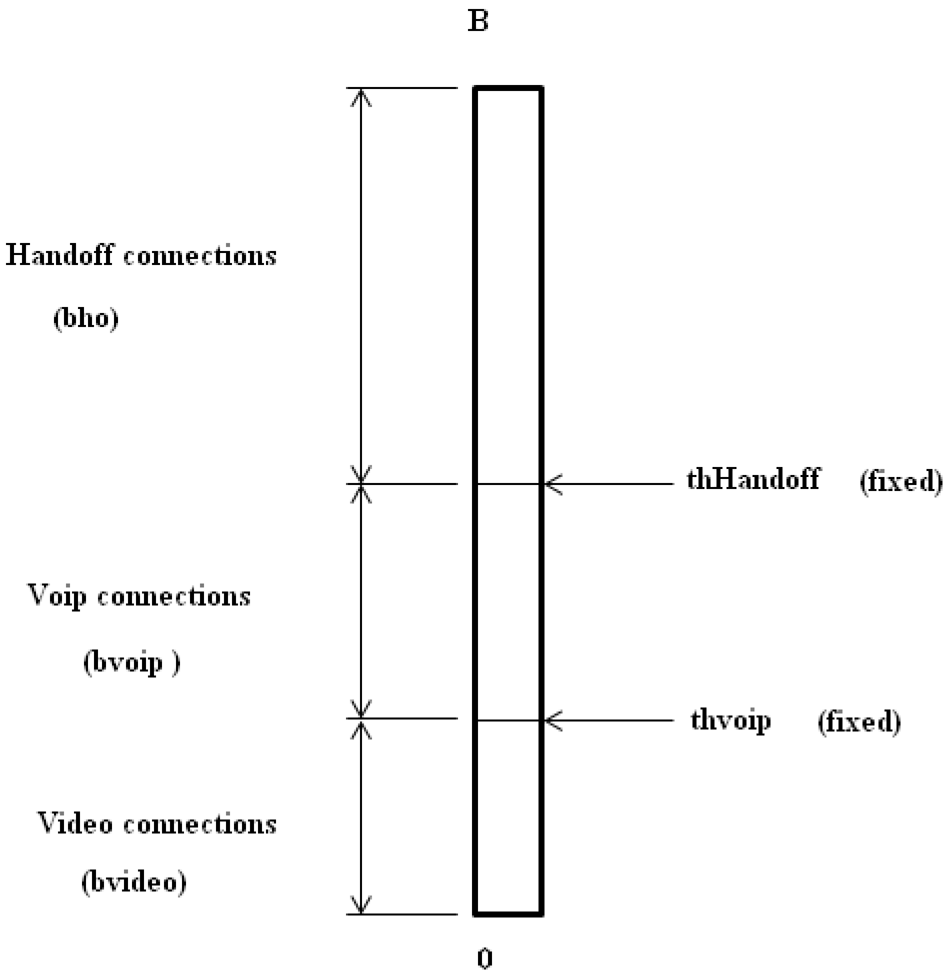

Figure 4.1: Static Bandwidth Reservation Scheme.

The total bandwidth that the eNB can allocate to the connections is denoted as ***B***. The boundary between the reserve of handoff and the new call of VoIP is denoted as "*thH*andoff" (handoff threshold). The boundary between the reserves of the VoIP calls and video calls is denoted as "thvoip" (VoIP threshold).

Also the bandwidth reserved for handoff connections corresponds to (*B* - *thHandoff*), the bandwidth reserved for the VoIP calls is (*thHandoff* - *th*voip), and for the video calls is (*thvoip*).

Figure 4.2 shows the adaptive bandwidth reservation method where the thresholds are dynamically adjusted to avoid the waste of reserved bandwidth and maintain the QoS of already admitted connections and prioritize handoff call over new call and prioritize VoIP over Video type.

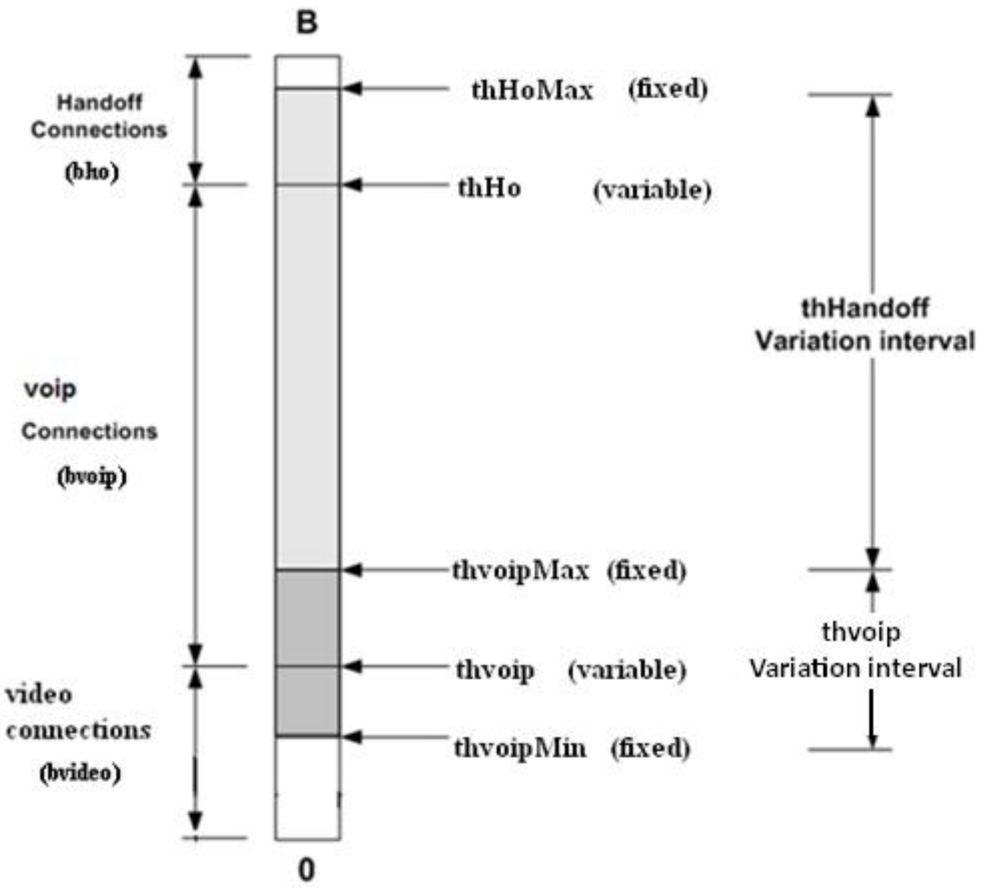

Figure 4.2: Bandwidth Reservation with Dynamic Threshold Scheme.

The total bandwidth that the eNB can allocate to the connections is denoted as **B**. The boundary between the reserves of handoff and new call of VoIP is denoted as "*thH*o" (handoff threshold). The boundary between the reserves of the VoIP calls and video calls as "thvoip" (VoIP threshold).

The portion of the bandwidth *B* already allocated to the existing handoff is b_{ho}, the VoIP call is b_{voip} and for video call is b_{video}, and b_{req} as the amount of bandwidth that a connection requires before being admitted. b_{req} for handoff calls, b_{req2} for VoIP calls, and b_{req3} for video calls.

The threshold "*thHo*" varies within the range [*thvoipMax, thHoMax*] and its initial value is [(*thHoMax* - *thvoipMax*) * 0.8]. The threshold "*thvoip*" varies within the range [*thvoipMin, thvoipMax*] and its initial value is [(*thvoipMax* – *thvoipMin*)/2].

B is split into segments to provide bandwidth reserves to the different types of traffic. The bandwidth reserved for handoff connections corresponds to (*B* - *thHo*). The bandwidth reserved for the VoIP calls is (*thHo* - *th*voip), and for the video calls is (*thvoip*). The admission of a connection by the enodeB obeys the following priority order:

Handoff connection, VoIP connection then *Video connection.*

Table 4.1 shows the parameters used in the simulations for both bandwidth reservation methods.

Table 4.1: The Simulation Parameters

Parameters	Symbol	Value
Total bandwidth of the eNB allocated to the connections	B	10Mbps
The required bandwidth for handoff calls	b_{req}	96Kbps
The required bandwidth for VoIP calls	b_{req2}	96Kbps
The required bandwidth for video calls	b_{req3}	480Kbps

4.3 Simulation Flow chart

Figure 4.3 shows the simulation flowchart of the static bandwidth reservation method. When a call request arrives to the network, it is either classified as handoff call or new call.

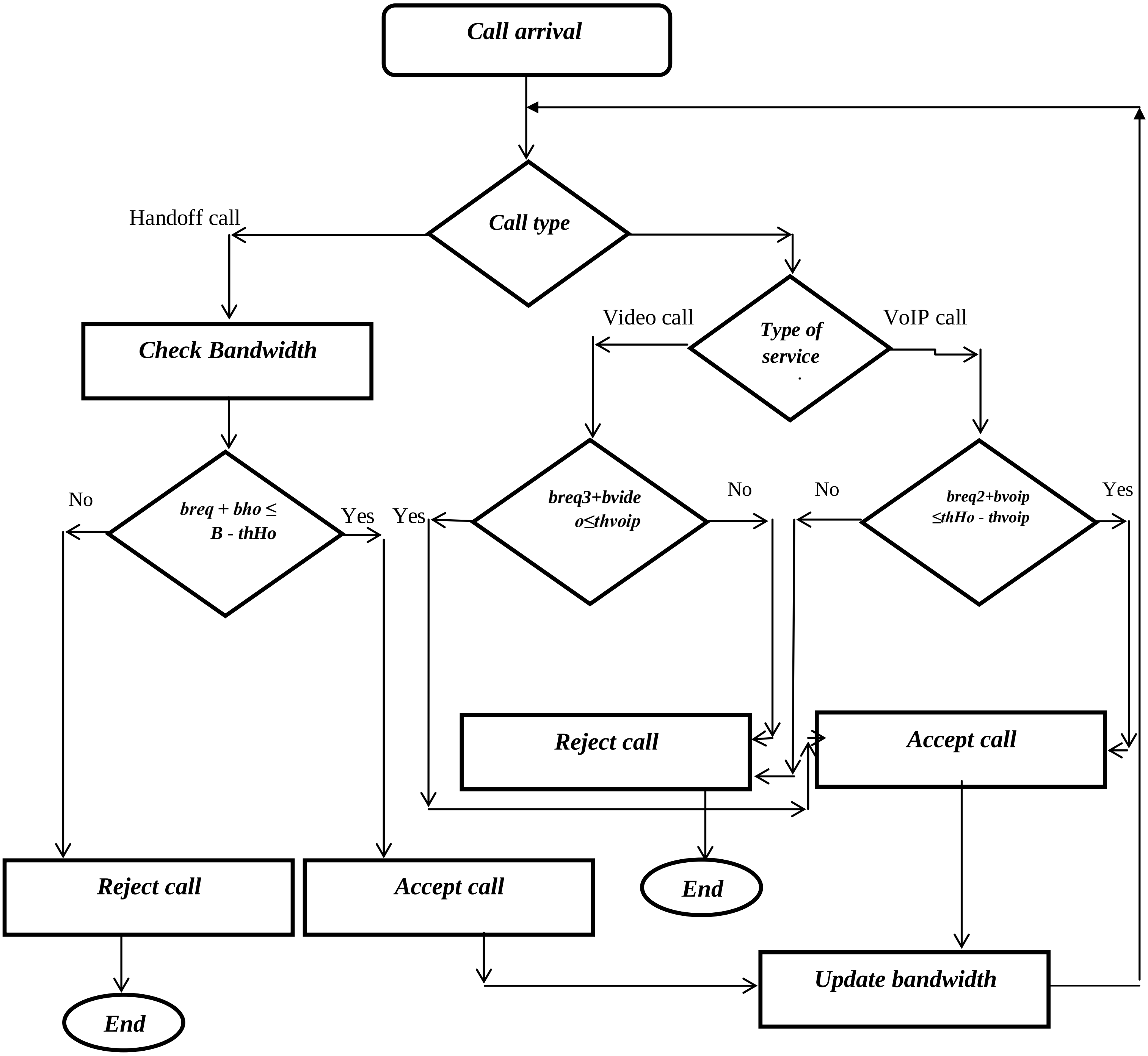

Figure 4.3: Flowchart of Static Bandwidth Reservation Method

If the call is a handoff connection, it will be admitted if:

$$(breq + bho) \leq (B - thHo)$$

If the connection is admitted, bho will be updated by:

$$bho = bho + breq$$

If the condition is not satisfied and handoff calls occupied all the reserved bandwidth then the new request will be rejected.

On the other hand, if the call request is new call it must be classified either as a voice over IP call (VoIP) or a video call.

If it is a VoIP call, it will be admitted if:

$$(breq2 + b_{voip}) \leq (thHo - thvoip)$$

If the connection is admitted, b_{voip} will be updated by:

$$b_{voip} = b_{voip} + breq2$$

If the condition is not satisfied and the reserved bandwidth of the VoIP is occupied the new call will be rejected.

If the call is a video call, it will be admitted if:

$$(breq3 + b_{video}) \leq (thvoip)$$

If the connection is admitted, b_{video} will be updated by:

$$b_{video} = b_{video} + breq3$$

If the condition is not satisfied and video calls occupied all the reserved bandwidth the new call will be rejected.

Figure 4.4 shows the simulation flowchart of the adaptive bandwidth reservation method. When a call request arrives to the network, it will be classified either as handoff call or new call.

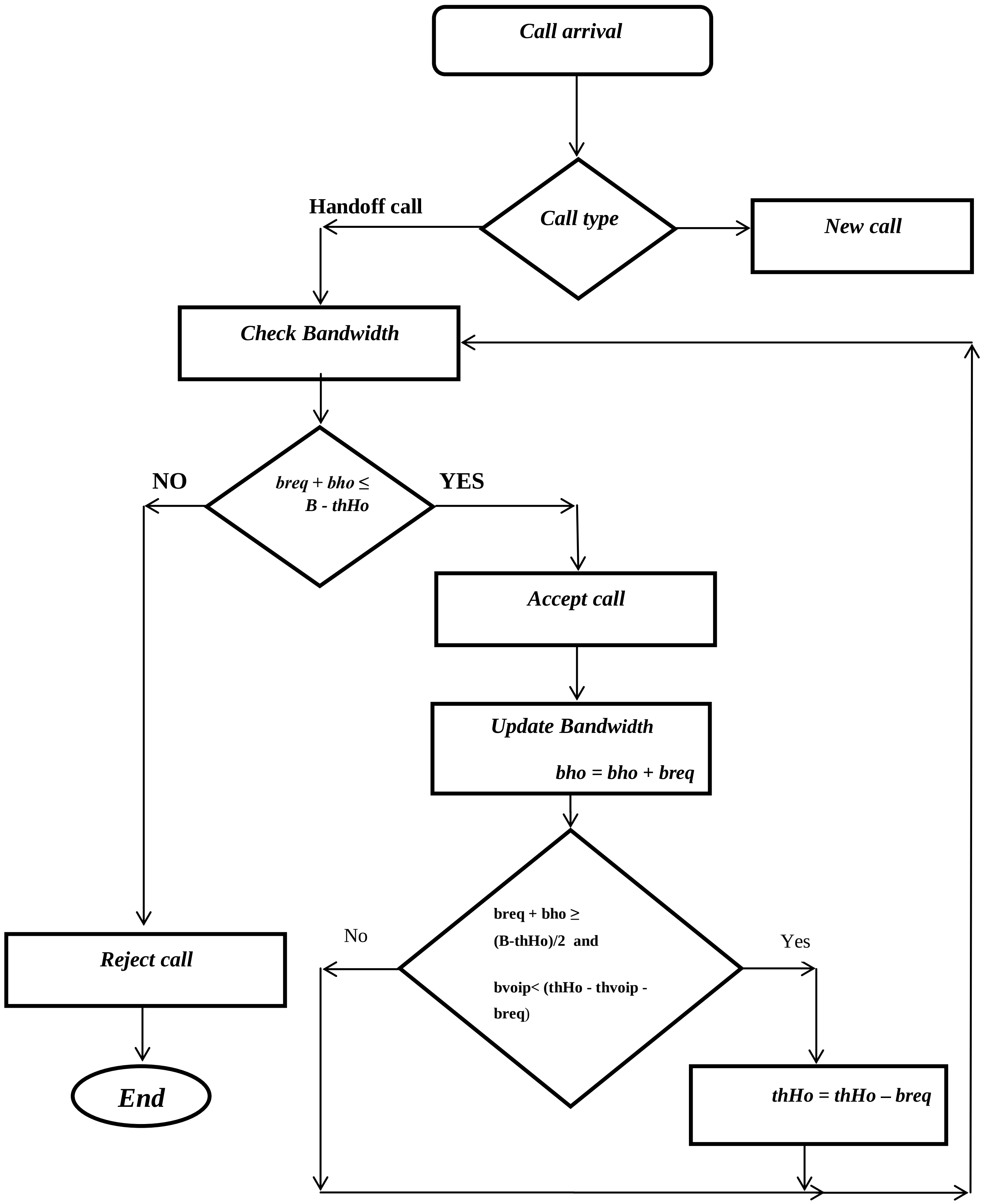

Figure 4.4: Flowchart of Adaptive Bandwidth Reservation Method (Handoff Call)

If the call is a handoff connection, it will be admitted if:

$$(breq + bho) \leq (B - thHo)$$

When the call connection is admitted, the handoff bandwidth (bho) will be updated by:

$$bho = bho + breq$$

After the update of *bho*, if the following condition is satisfied:

$$((breq + bho) \geq (B\text{-}thHo)/2 \text{ and } (b_{voip}) < (thHo - thvoip - breq2))$$

Then the handoff threshold (*thHo)* will be reduced by *breq* (limited to the value of thvoipMax), that is:

$$thHo = thHo - breq$$

The purpose of this condition is to increase the size of the reserve for the handoff connections, the threshold handoff (*thHo)* only changes if the occupation of the reserve for handoff connections reaches the value [(*B-thHo) / 2*]. This avoids the decrease of the reserve for VoIP calls before the occupation of half of the reserve for handoff connections. If the condition is not satisfied and handoff calls occupied all the reserved bandwidth then the new request will be rejected.

On the other hand, if the call request is a new call then it must be classified either as a voice over IP call (VoIP) or a video call.

Figure 4.5 shows the simulation flowchart of the adaptive bandwidth reservation method for new call.

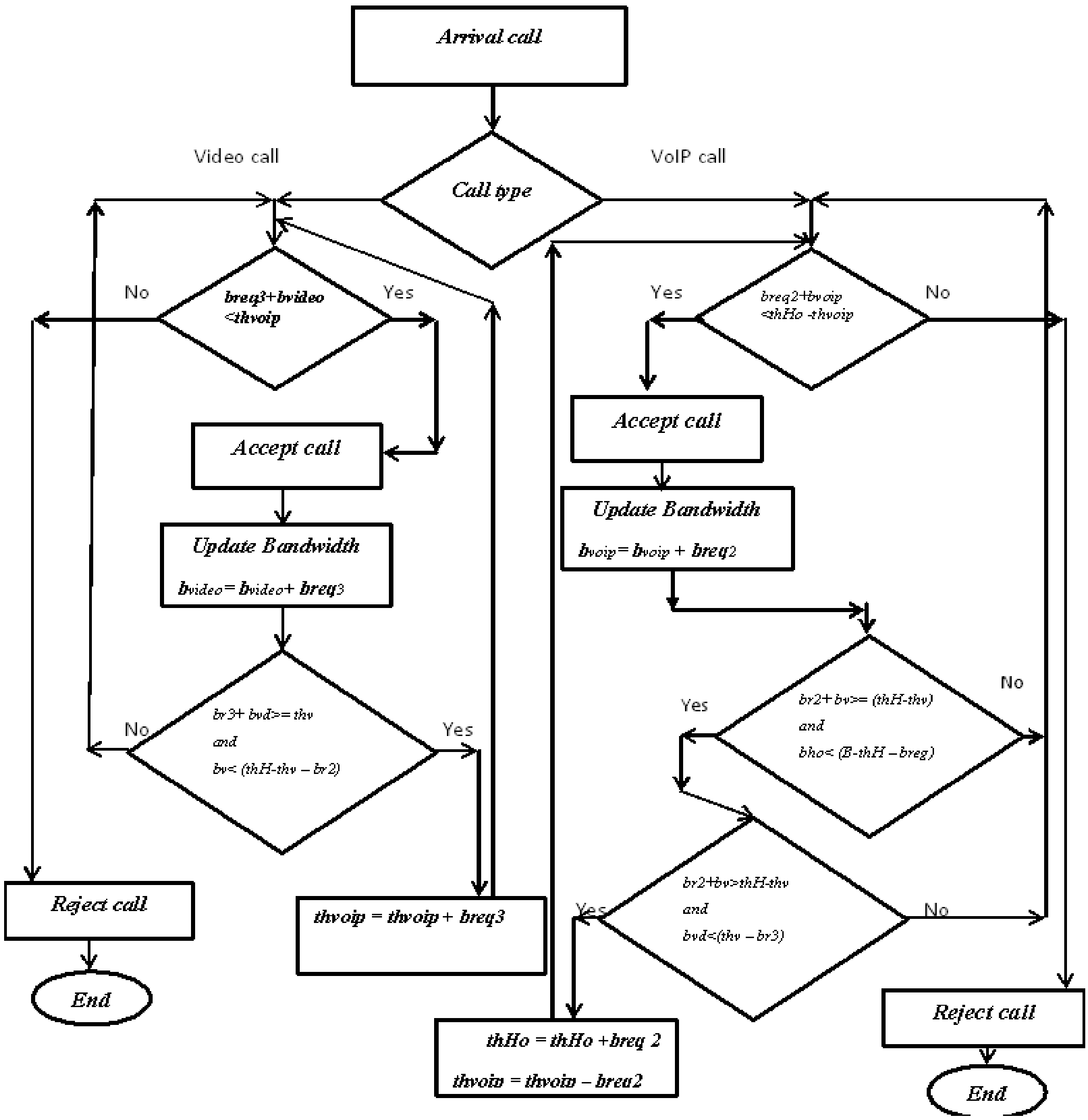

Figure 4.5: Flowchart of Adaptive Bandwidth Reservation Method (New Call)

br2: breq2, bv: b_{voip}, thH: thHo

thv: thvoip , bvd: bvideo , br3: breq3

When a new call arrives it is classified either as a VoIP call or a video call.

If it is a VoIP call then it will be admitted if:

$$(breq2 + b_{voip}) \leq (thHo - thvoip)$$

After the connection is admitted, b_{voip} will be updated by:

$$b_{voip} = b_{voip} + breq2$$

After the update of b_{voip}, if the following condition is satisfied:

$$((breq2 + b_{voip}) \geq (thHo-thvoip) \text{ and } (bho \leq B - thHo–breq))$$

Then the handoff threshold (*thHo*) will be increased by *breq* (limited to the value of *thHoMax),* that is:

$$thHo = thHo + breq2$$

And, if the following condition is satisfied:

$$((breq2 + b_{voip}) \geq (thHo-thvoip) \text{ and } (b_{video} < (thvoip – breq3))$$

The VoIP threshold *thvoip* will be decreased by *breq2*, (limited to the value of (*thvoipMin)* that is:

$$thvoip = thvoip – breq2$$

The purpose of these conditions is to increase the size of the reserve for VoIP calls. If the condition is not satisfied and VoIP calls occupied all the reserved bandwidth then the new request will be rejected.

If the type of call is a video call, then it will be admitted if:

$$(breq3 + b_{video}) \leq (thvoip)$$

If the connection is admitted, the video bandwidth b_{video} will be updated by:

$$b_{video} = b_{video} + breq3$$

After the update of b_{video}, if the following condition is satisfied:

$$(breq3 + b_{video}) \geq (thvoip) \text{ and } b_{voip} < (thHo-thvoip– breq2)$$

The VoIP threshold *thvoip* will be increased by *breq*3 (limited to the value of *(thvoipMax*), that is:

$$thvoip = thvoip + breq3$$

The purpose of these conditions is to increase the size of the reserve for video calls. If the condition is not satisfied and the video calls have occupied all the reserved bandwidth then the new request will be rejected.

4.4 Results and Discussion

In this section both the adaptive and static bandwidth reservation methods were simulated to compare their performance on the network.

Different scenarios were carried out using different values of the bandwidth reserved. Three types of services were considered; handoff calls, VoIP calls and video calls. The simulation assumes that 150 call requests arrive per 10 seconds.

Scenario One: In this scenario, the bandwidth reserved for video calls b_{video} was set to be 1.5MHZ for both methods. While the bandwidth reserved for both the handoff *bho* and the VoIP b_{voip} calls were varied. Table (4.2) shows the different cases of bandwidth reservation for both methods.

Table 4.2: Different Cases of Bandwidth Reservation for Handoff and VoIP calls

Static and Adaptive Methods	Case 1	Case 2
bho	6 MHz	4.6 MHz
b_{voip}	2.5 MHz	3.9MHz

Table 4.3 and 4.4 shows the total and admitted number of calls for handoff, VoIP and video calls in both cases. Table 4.3 shows that the bandwidth

reserved for handoff in both methods is sufficient to occupy the handoff admitted calls. This resulted in both algorithms having the same number of users which is the max number. The VoIP, on the other hand, showed a poor performance in the adaptive method since the threshold th_{voip} was adjusted to accommodate more incoming video calls than VoIP calls.

Table 4.3: Total and Admitted Number of Calls for Handoff, VoIP and Video Calls in Case 1

Case 1	**Handoff calls**		**VoIP calls**		**Video calls**	
	Total number of calls	Admitted calls	Total number of calls	Admitted calls	Total number of calls	Admitted calls
Static Method	81	62	41	26	28	3
Adaptive Methods	70	62	40	13	40	6

Table 4.4: Total and Admitted Number of Calls for Handoff, VoIP and Video Calls in Case 2

Case 2	**Handoff calls**		**VoIP calls**		**Video calls**	
	Total number of calls	admitted calls	Total number of calls	admitted calls	Total number of calls	admitted calls
Static Method	70	47	31	31	49	3
Adaptive Methods	78	50	34	7	38	9

Table 4.4 shows that the bandwidth reserved for handoff in the static method was sufficient to occupy the handoff admitted calls. While, in the adaptive method there were more incoming handoff calls. This resulted in

the threshold th_{Ho} being adjusted to accommodate more handoff calls. The table also shows that the threshold th_{voip} was adjusted to accommodate more incoming video calls. Both the handoff and video calls resulted in a drastically poor performance in the VoIP calls than the static method.

Figure 4.6 and 4.7 shows the dropping probability of handoff and the blocking probability of both VoIP and video calls for the two different cases.

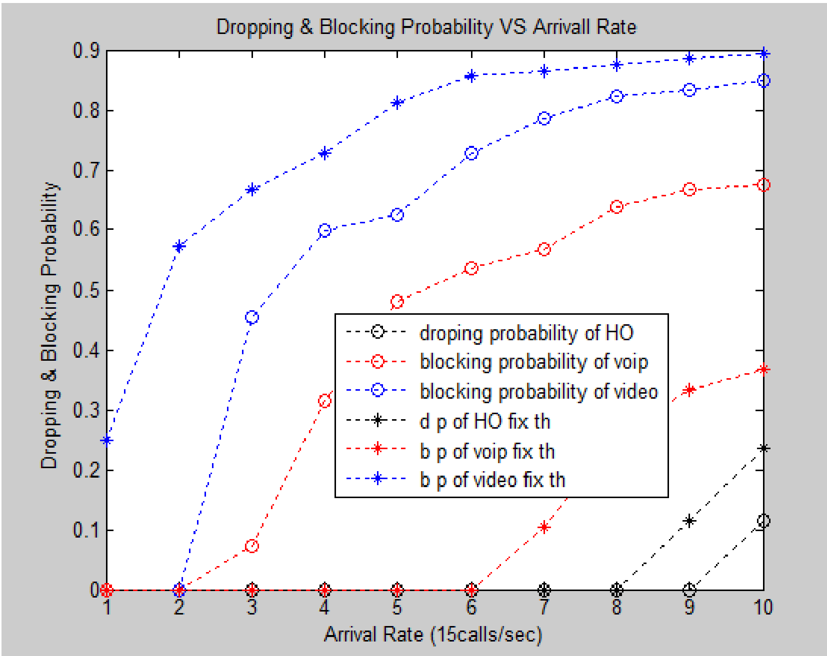

Figure 4.6: Dropping and Blocking Probability Vs Arrival Rate (calls/sec)

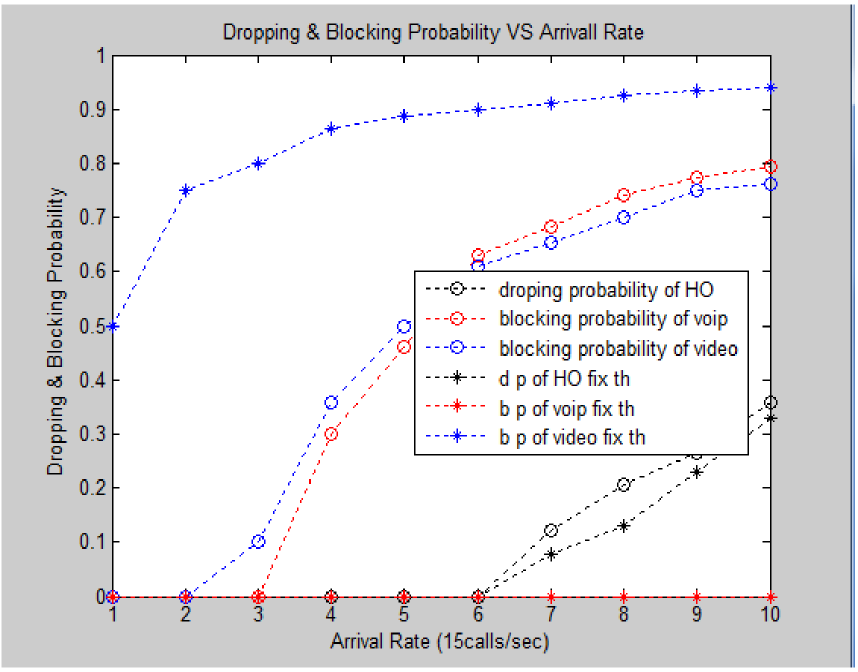

Figure 4.7: Dropping and Blocking Probability Vs Arrival Rate (calls/sec)

Both Figure 4.6 and 4.7 show that the performance of the handoff and video was better in the adaptive than in the static method. This is due to the fact that the calls are admitted randomly and both thresholds the th_{Ho} and the th_{voip} were adjusted to accommodate more incoming handoff and video calls than VoIP calls, resulting in a poor performance for the VoIP calls. The figures also show that as the bandwidth reserved increases, the dropping probability decreases as more calls are allowed to enter the network.

Scenario Two: In this scenario, the bandwidth reserved for handoff calls *bho* was set to 6 MHZ in both cases. While the bandwidth reserved for both the video b_{video} and VoIP b_{voip} calls were varied. Table (4.5) shows the different cases of bandwidth reservation for both methods.

Table 4.5: Different Cases of Bandwidth Reservation for Video and VoIP

Static and Adaptive Methods	Case 1	Case 2
b_{voip}	2.5 MHz	2 MHz
b_{video}	1.5 MHz	2 MHz

Table 4.6 and 4.7 shows the total and admitted number of calls for handoff, VoIP and video calls in both cases

Table 4.6: Total and Admitted Number of Calls for Handoff, VoIP and Video Calls in Case 1

Case 1	Handoff calls		VoIP calls		Video calls	
	Total number of calls	admitted calls	Total number of calls	admitted calls	Total number of calls	admitted calls
Static Method	77	62	30	26	43	3
Adaptive Methods	73	62	43	10	34	7

Table 4.6 shows that the bandwidth reserved for handoff in both methods is sufficient to occupy the handoff admitted calls. This resulted in both the static and adaptive methods having the same number of users which is the max number. The VoIP, on the other hand, showed a poor performance in the adaptive method since the threshold th_{voip} was adjusted to accommodate more incoming video calls than VoIP calls.

Table 4.7: Total and Admitted Number of Calls for Handoff, VoIP and Video Calls in Case 2

Case 1	Handoff calls		VoIP calls		Video calls	
	Total number of calls	admitted calls	Total number of calls	admitted calls	Total number of calls	admitted calls
Static Method	71	62	39	20	40	4
Adaptive Methods	70	62	38	5	42	7

Table 4.7 shows that the bandwidth reserved for handoff was sufficient in both methods. Since the calls are randomly generated, it was noticed that more video calls arrived to the network than VoIP calls. This resulted in the threshold th_{voip} to be adjusted to accommodate the incoming video calls resulting in a poor performance for the VoIP calls.

Figure 4.8 and 4.9 shows the dropping probability of handoff and the blocking probability of both VoIP and video calls for two different cases.

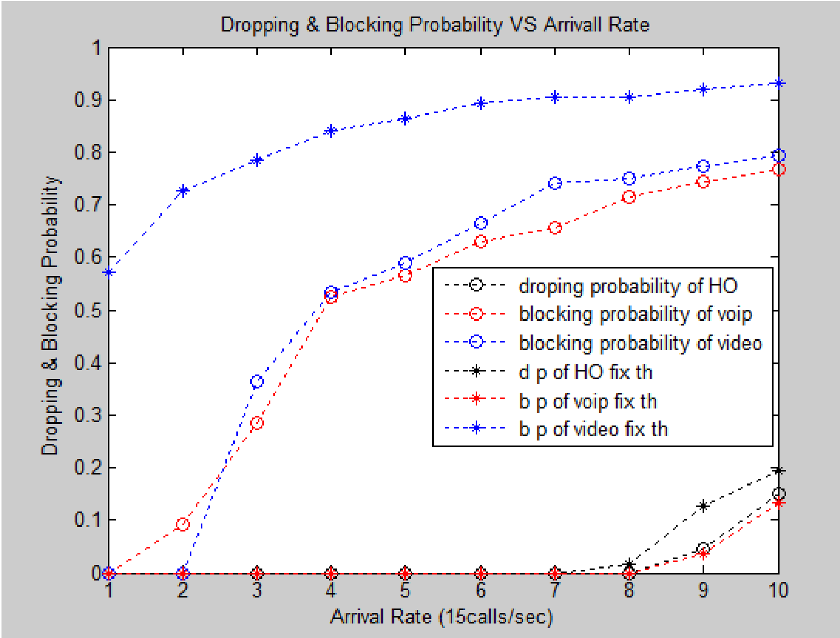

Figure 4.8: Dropping and Blocking Probability Vs Arrival Rate(calls/sec)

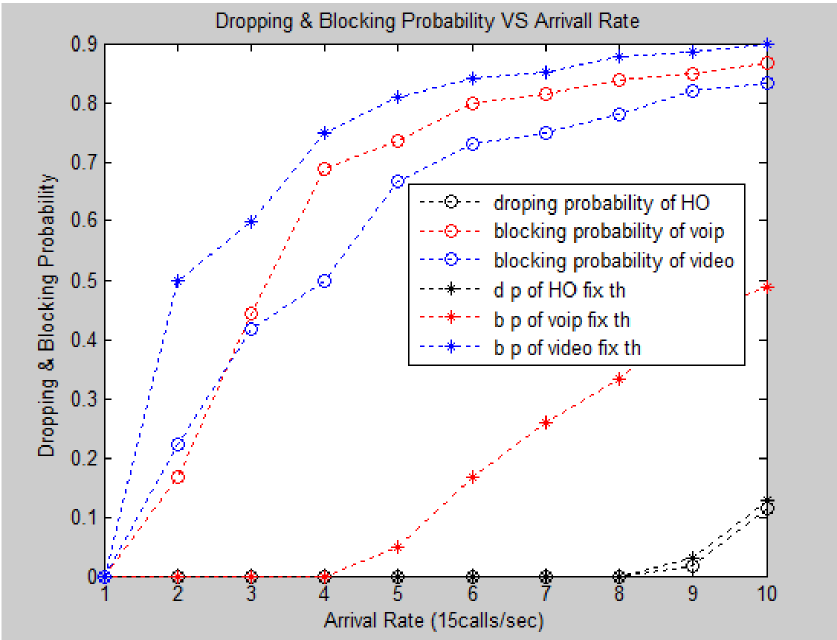

Figure 4.9: Dropping and Blocking Probability Vs Arrival Rate (calls/sec)

Both Figure 4.8 and 4.9 shows that since the bandwidth reserved for handoff calls was big, around 60%, the dropping probability was small in both methods. Figure 4.9 shows a tremendous increase in the blocking probability of the VoIP in the adaptive method and this is due to the reduction in the bandwidth reserved for the VoIP, as well as the adjustment of the thresholds to accommodate more video calls.

Scenario Three: In this scenario, the bandwidth reserved for VoIP calls b_{voip} was set to 3MHZ in both methods .While the bandwidth reserved for both the handoff *bho* and the video b_{video} calls were varied. Table (4.8) shows the different cases of bandwidth reservation for both methods.

Table 4.8: Different Cases of Bandwidth Reservation for Handoff and Video

Static and Adaptive Methods	**Case 1**	**Case 2**
bho	5.5 MHz	5 MHz
$\boldsymbol{b_{video}}$	1.5 MHz	2 MHz

Table 4.9 and 4.10 shows the total and admitted number of calls for handoff, VoIP and video calls in both cases

Table 4.8: Total and Admitted Number of Calls for Handoff, VoIP and Video Calls in Case 1

Case 1	**Handoff calls**		**VoIP calls**		**Video calls**	
	Total number of calls	admitted calls	Total number of calls	admitted calls	Total number of calls	admitted calls
Static Method	75	57	36	31	39	3
Adaptive Methods	76	57	35	7	39	8

Table 4.9: Total and Admitted Number of Calls for Handoff, VoIP and Video Calls in Case 2

Case 2	**Handoff calls**		**VoIP calls**		**Video calls**	
	Total number of calls	admitted calls	Total number of calls	admitted calls	Total number of calls	admitted calls
Static Method	77	52	30	30	43	4
Adaptive Methods	73	52	43	11	34	8

Table 4.8 and 4.9 shows that in the static method, calls are admitted depending on the bandwidth reserved for each type of call. While in the adaptive method the thresholds are adjusted to accommodate the incoming call on the bases of first come first serve. The tables show that there was an increase in the VoIP admitted calls when the bandwidth reserved for the handoff was reduced and the reserved bandwidth of the video reached its maximum.

Figure 4.10 and 4.11 show the dropping probability of handoff and the blocking probability of both VoIP and video calls for two different cases.

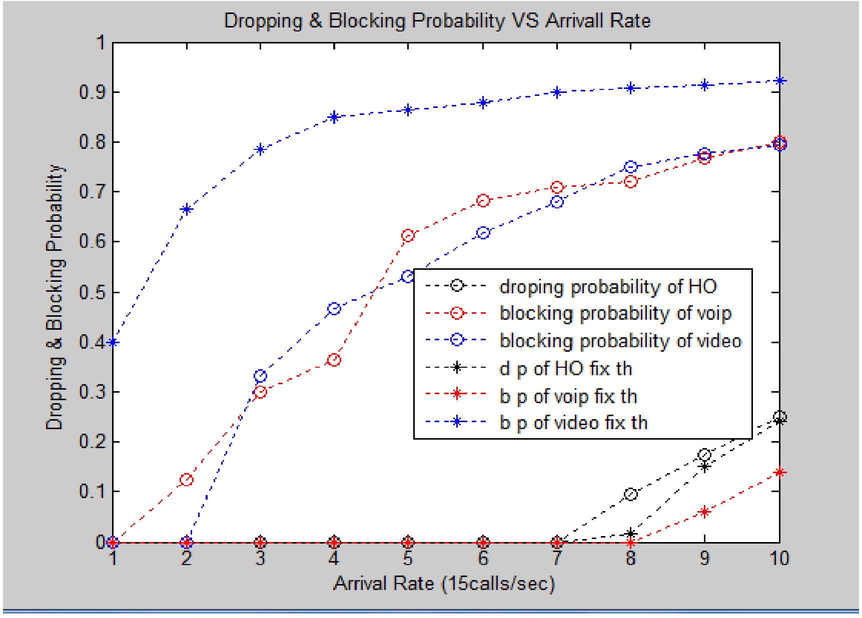

Figure 4.10: Dropping and Blocking Probability Vs Arrival Rate (calls/sec)

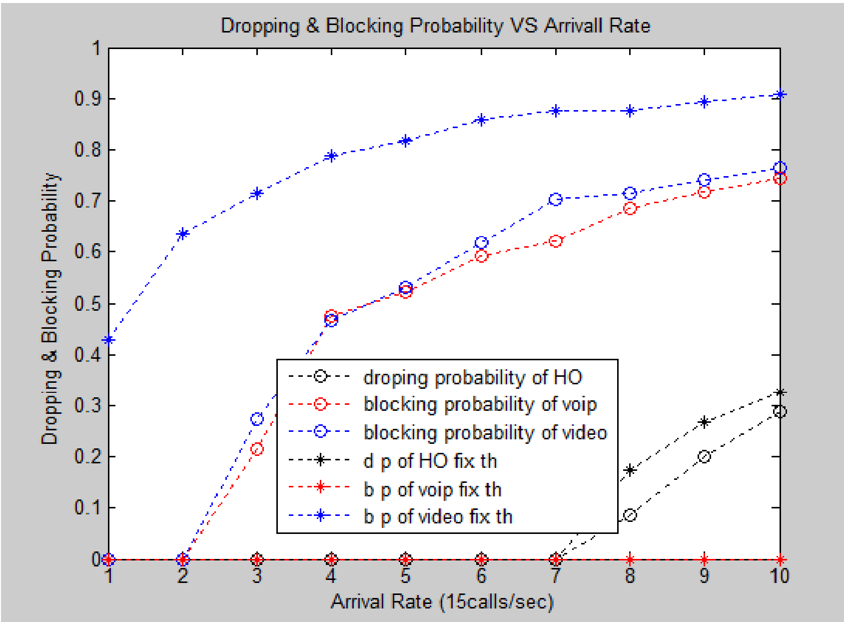

Figure 4.11: Dropping and Blocking Probability Vs Arrival Rate (calls/sec)

From Figure 4.10 and 4.11 it can be seen that the VoIP in the static method had the lowest blocking probability than both the handoff and video. It was noticed that since the bandwidth reserved for the VoIP was relatively big, the blocking probability of the VoIP decreased when the bandwidth reserved for the handoff was reduced as shown in Figure 4.11.