University Of Cape Town

Department of Electrical Engineering

Mobile Wireless Networks

Prepared by:
Tawanda Muzanenhamo
MZNTAW004

Prepared for:

Dr Olabisi E Falowo

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Abstract

This paper details on the designing, modeling and analysis of the performance of load balancing Joint call admission control algorithm which is used to when allocating resources in heterogeneous cellular networks.

Introduction

Heterogeneous networks have enabled the evolution of networks from one generation to the other so that they can accommodate and fully utilize new technologies whilst also fully utilizing the infrastructure of legacy networks that have been built already. A heterogeneous cellular network is made up of many Radio Access Technologies (RATs) which enable users from different wireless technologies to connect to the available network.

The amount of resources in a heterogeneous network is finite like any other network resources and this leads to the rise of the need to manage the resources efficiently in order to have an acceptable network performance and enhance the networks Quality of Service (Qos). The resources in the networks are managed by Radio Resource Management (RRM). The Radio Resource Management is also responsible for deciding how different network subscribers are allocated resources.

Literature Review

Radio Access Technologies

Global System for Mobile (GSM) communication

GSM was developed as the first step towards 2nd Generation networks. It was built so that it would have large capacity relative to the previous analogue network systems. GSM supports speech, Short Message Service (SMS) and data. The 2G technology offers good quality when it comes to its service whilst also enabling user mobility. 2nd Generation mobile systems uses 8 time slots for each 200 kHz carrier in TDMA. The users have different frequencies (FDMA) and they are separated by the 200 kHz of each carrier.

GSM architecture.

GSM network is divided into:

- Mobile station (MS)
- Base Station Subsystem (BSS)
- Operation Support System (OSS)
- Network Switching Subsystem (NSS)

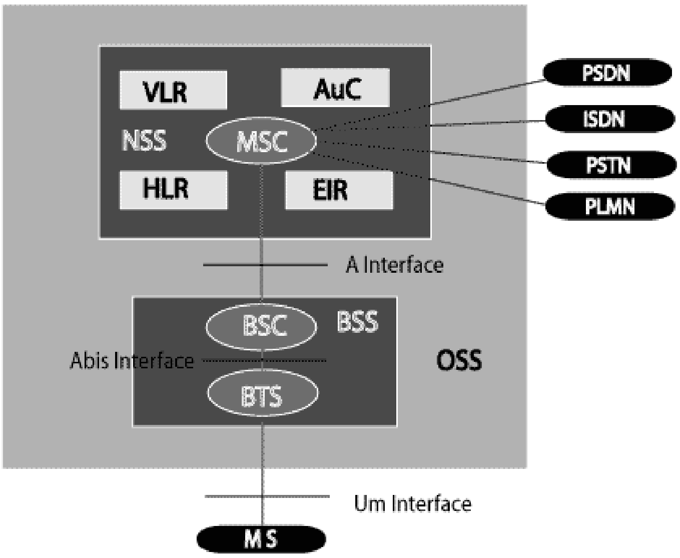

Figure 1: GSM Architecture

GSM offers three basic types of services:

- Telephony Services
- Data Services
- Supplementary Services.

Teleservices/Telephony Services

Voice calls are the most basic teleservice supported by GSM, they are executed at full rate of 13 kbps and during a full rate voice call 1 time slot is used.

Data Services.

The data services are used to send and receive data and they have contributed massively to the rise of the internet. GSM data services have a data transfer rate of 9.8 k.

Supplementary Services.

These services include call forwarding, call waiting, caller identification, barring of outgoing calls and multi-party calls.

Long Term Evolution (LTE) and LTE Advanced

LTE known as 4G was developed as a successor of 3G UMTS. LTE supports converged data and Voice over IP because it uses packet switching instead of using both packet switching and circuit switching. LTE provides higher data speeds with low latency and utilizes Orthogonal Frequency Division Multiplexing (OFDM). In OFDM data streams are split into separate sub streams and each sub-stream is modulated with a separate orthogonal carrier which allows high data bandwidths to be transmitted and also provides high resistance against interference. OFDM is used in downlink and SC-FDMA is used in uplink because it has a small peak average power.

Key Features of LTE and LTE advanced

- Peak Download rates of up to 1Gbps
- Improved User Mobility
- Multihop Solutions
- Backwards compatible with 2G and 3G networks for call handover
- Scalable Bandwidth

Heterogeneous Network.

The heterogeneous network analyzed in this paper have the following specifications:

- Two RAT heterogeneous cellular networks
- Collocated calls
- Handoff calls are prioritized over new calls
- At Least one type of calls supported
- Some users have double-mode terminals

The figure below illustrates a Two RAT heterogeneous network.

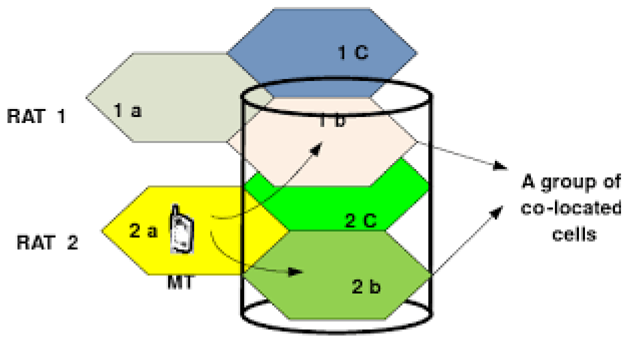

Figure 2: Two RAT Heterogenous Network []

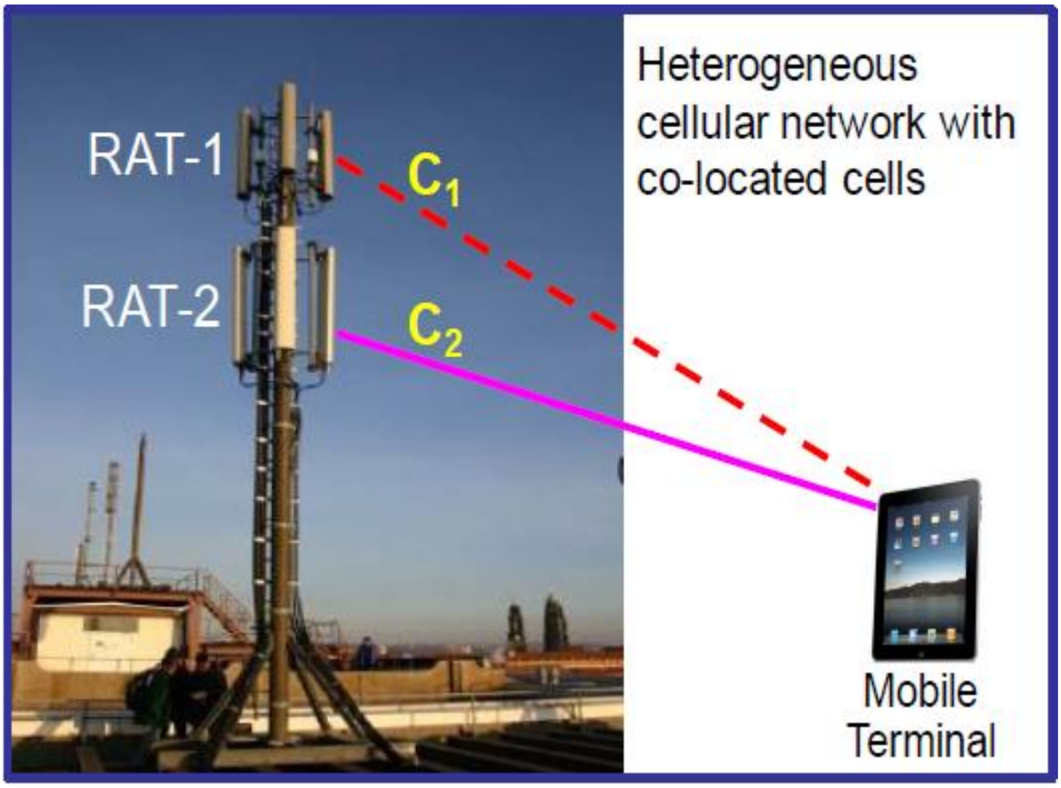

Figure 3: Heterogenous Network with co-located cells []

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The Joint Call Admission Control (JCAC).

The resources in a network need to be utilized efficiently because they are scarce, the need to efficiently utilize network resource has led to the rise of the Radio Resource Management (RRM). In order to ensure that resources are fully utilized, RRM with the aid of JCAC decides whether or not a call can be accepted into a constrained network without violating the service made to already admitted calls. The JCAC also aids in the decision of the RAT that will accept the call. The JCAC is triggered by the following events:

- New call arrival
- Handoff call arrival
- Bearer Modification

The JCAC are required to have the following features:

- Optimality
- Simplicity
- Stability
- Scalability

The JCAC have the following objectives:

- Efficient Radio Resource Management
- Enhanced Quality of Service
- Overall Network Stability
- Overall Service Cost Reduction

Methodology.

The key findings of this report are on the call dropping and blocking probabilities which are defined as follows:

- **Call Blocking Probability -** It is the ratio of the amount of calls denied access to the network and the number of admissible states
- **Call Dropping Probability -** It is the ratio of number of calls dropped from the network and the number of calls already in the network

Both the call blocking and dropping probabilities are calculated using the admissible states space **S** of the network.

A java program which calculates the call dropping and blocking probabilities was created. The program also calculates the size of the admissible state space **S**, dropping state and blocking state which are used during the calculations of the dropping and blocking probabilities.

Current State

$$\Omega = (m1;\ n1;\ m2;\ n2)$$

Equation 1 Current state

Admissible state S shows the combination of users which can supported by the network at once.

$$\mathbf{S} = \{\Omega = (m1;\ n1;m2;n2;\ ) : ((m1+n1)b \leq c1) \cap (m1)b \leq t1 \cap (m2+n2)b \leq c2 \cap (m2)b \leq t2\}$$

Equation 2: Admissible state

The Defined Constants.

m_i	New Class- i calls in RAT j
n_i	Handoff class- i calls in RAT j
c1	RAT 1 bandwidth (Capacity)
c2	RAT 2 bandwidth (Capacity)
t1	Max bandwidth before blocking new calls RAT1
t2	Max bandwidth before blocking new calls RAT2

Table 1 Defined Constants

Flow Chart

The flowchart below illustrates how calls are admitted or rejected into the network. Connections to particular RATs are only possible when the mobile terminal is capable of connecting to the RAT. A call is admitted if and only if the mobile terminal is able to connect to the RAT and the constraints of the RAT are satisfied.

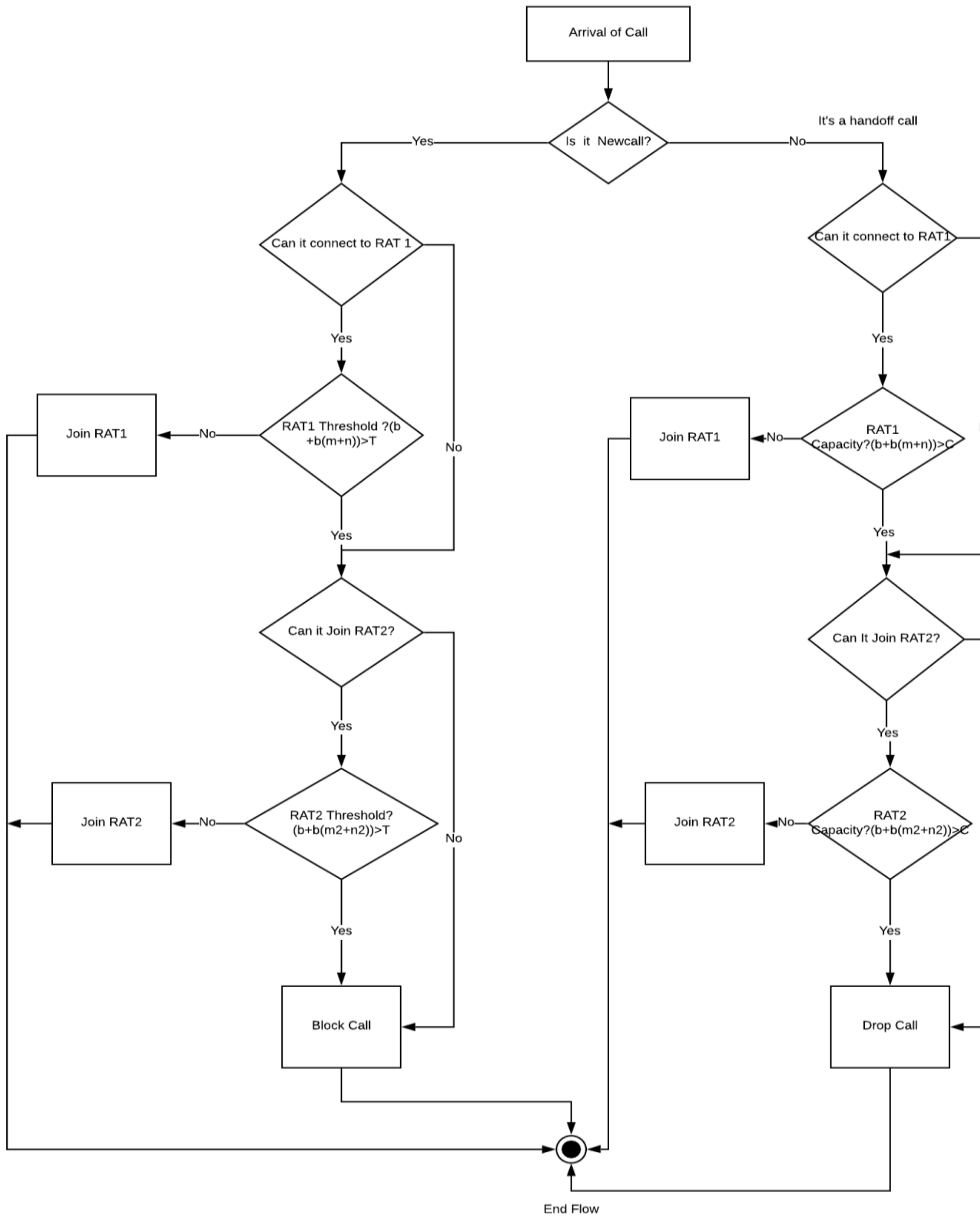

Figure 4 Call Admitting Flow Chart

Radio Access Technologies Specifications.

The default parameters of the heterogeneous network were set so that the initial state of the heterogeneous network can be found.

- RAT 1 Capacity c1 = 20
- RAT 2 Capacity c2 = 20
- RAT 1 Threshold t1 = 10
- RAT 2 Threshold t2 = 10

The network supports two types of calls:

- Voice Calls - Class A
- Data Calls - Class B

The basic bandwidth is assumed to be 1.
There are two heterogenous cellular networks with collocated cells.

- GSM
- LTE

Handoff calls are prioritized
One of the users have a double mode terminal.
Group A is the single mode connecting to RAT 1 and Group B is the Dual Mode connecting to RAT 2

Results

The Initial state of the Network with values specified above produced the results below.

Class of Call (Type)	Probability of Blocking New Calls	Probability of Dropping Handoff Calls
A	0.6875	0.0625
B	0.47265625	0.00390625

Table 2: Initial state of the network

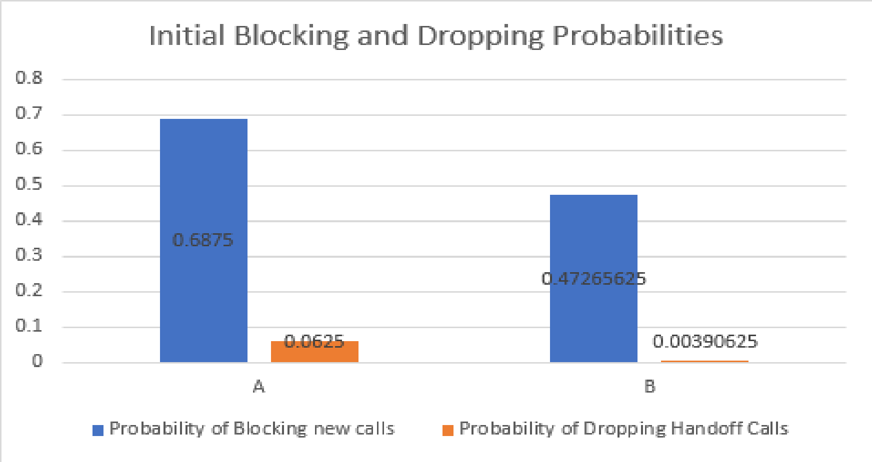

Figure 5: Initial State Bar graphs

The values obtained from the initial state of the network will be used to compare how the network changes when the following changes were made

- Effect of Increasing call arrival rate on call blocking and dropping probability.
- Effect of Increase in network capacity on call blocking and dropping probability.
- Effect of handoff call prioritization on call blocking and dropping probability.
- Effect of increasing the basic bandwidth unit per call on blocking and dropping probability.

Increasing Call Arrival Rate.

The effect of increasing call arrival rate on the call blocking and dropping probability is evaluated and the results are analyzed.
The formulas used to evaluate the effect of increasing new call arrival rate are shown below.

$$\rho_{\text{new}_{i,j}} = \frac{\lambda_{i,j}^{n}}{\mu_i^{n}} \quad \forall i, j,$$

$$\rho_{\text{han}_{i,j}} = \frac{\lambda_{i,j}^{h}}{\mu_i^{h}} \quad \forall i, j.$$

Equation 3: Calculating load generated

The first equation in Equation 3 shows how the the load generated by new calls is calculated and the second equation in Equation 3 shows the load calculated handoff calls is calculated. The results are then used to calculate the probabilities using the formula shown below.

$$P(s) = \frac{1}{G}\prod_{i=1}^{k}\prod_{j=1}^{J}\frac{\left(\rho_{\text{new}_{i,j}}\right)^{m_{i,j}}}{m_{i,j}!}\frac{\left(\rho_{\text{han}_{i,j}}\right)^{n_{i,j}}}{n_{i,j}!} \quad \forall s \in S,$$

Equation 4: Calculating the probability

With G being the normalization constant calculated using formula 5 below.

$$G = \sum_{s \in S} \prod_{i=1}^{k} \prod_{j=1}^{J} \frac{(\rho_{\text{new}_{i,j}})^{m_{i,j}}}{m_{i,j}!} \frac{(\rho_{\text{han}_{i,j}})^{n_{i,j}}}{n_{i,j}!}.$$

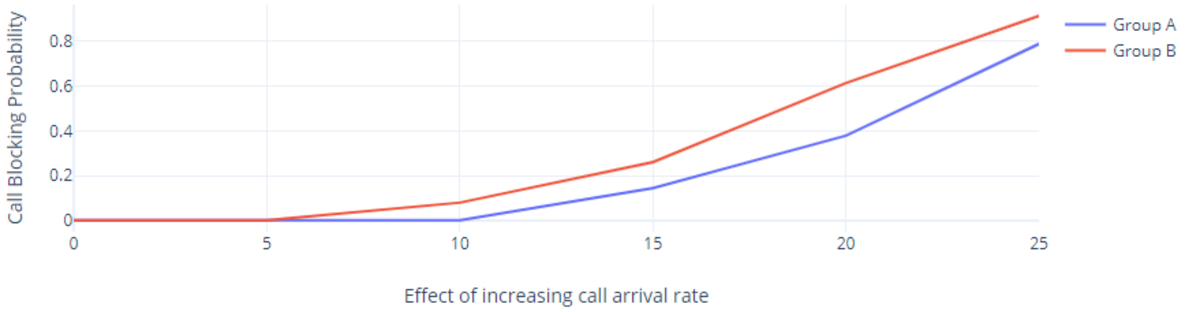

Figure 6 Effect of Increasing Call Arrival Rate for Group A and Group B

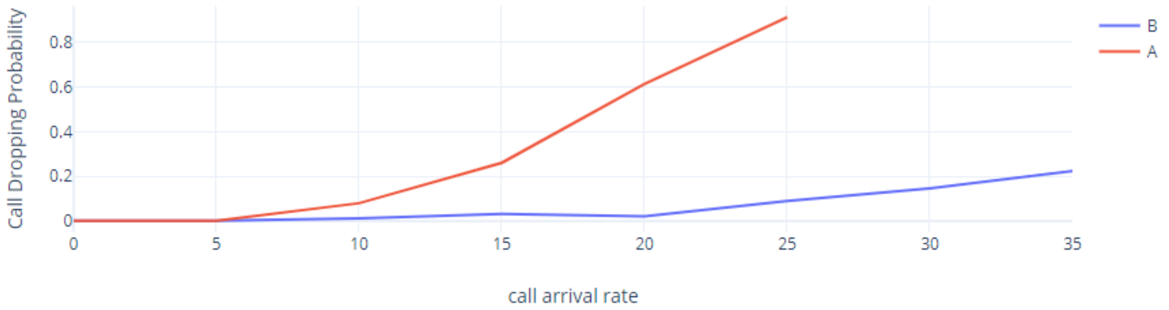

Figure 7: Effect of Increasing Call Arrival Rate on Call Dropping Probability

From the graphs above it can be seen that the probabilities of blocking and dropping new calls for both types of calls increases as the new call arrival rate is increased at an exponential rate.

Effect of Increasing Network Capacity on Call Blocking/Dropping Probability

The effect of increasing the network capacity of the RAT on the probability of blocking and dropping calls is illustrated on the graph below.

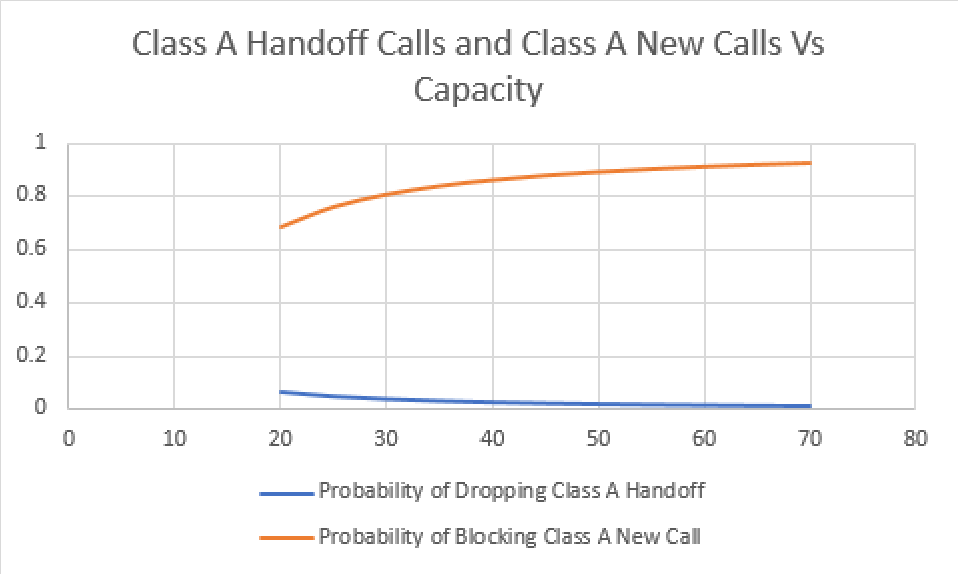

Figure 8: Effect of Increasing Network Capacity on Dropping and Blocking Probability.

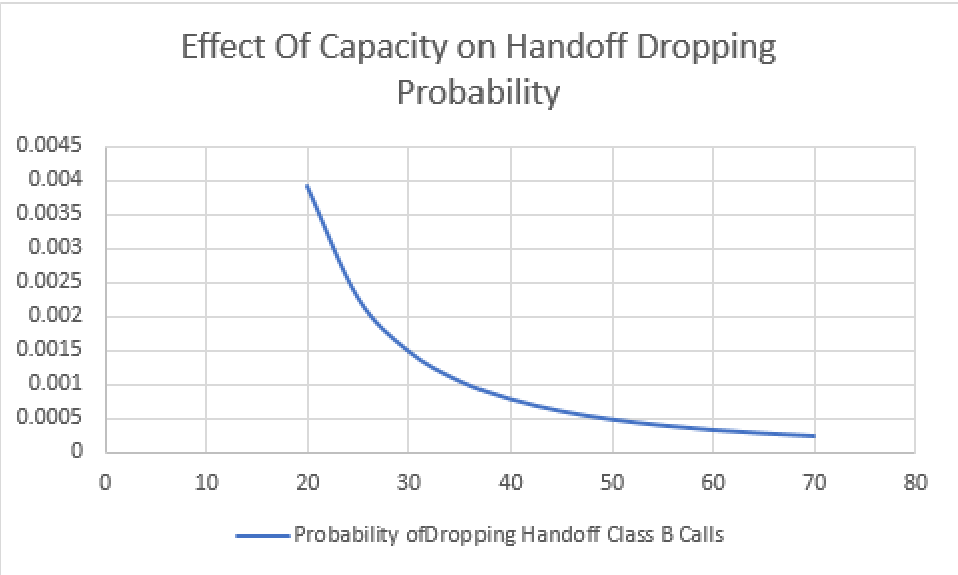

Figure 9: Effect of Increasing Capacity on Handoff Dropping Probability

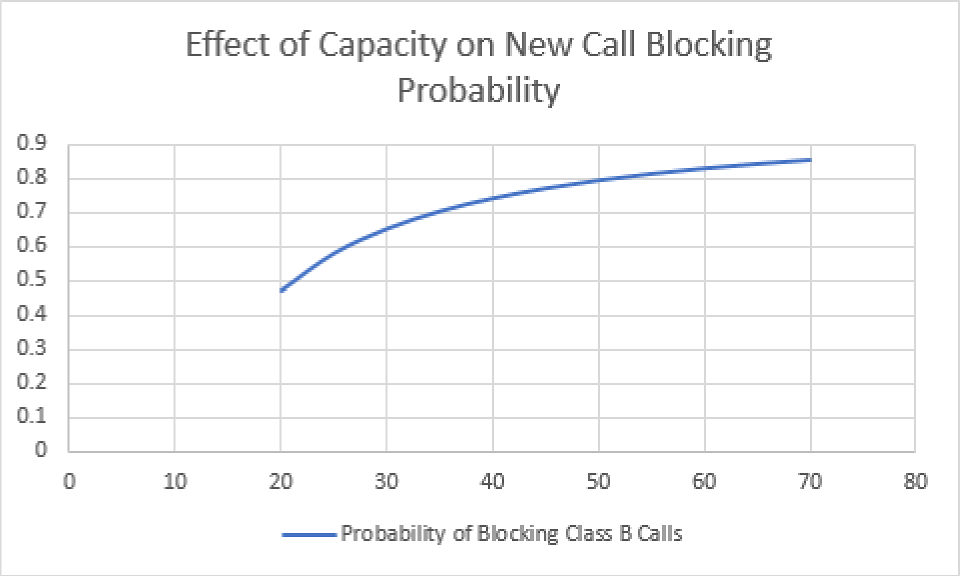

Figure 10: Effect of Increasing Capacity on New Call Blocking Probability

From the graphs above we can see that there is an increase in the new call blocking probability and a decrease in the dropping probability of handoff calls for both classes of calls.

Effect of handoff call prioritization on Call Blocking/Dropping Probabilities.

The effect of handoff call prioritization in the RATs on the probabilities of dropping handoff calls and blocking new calls is evaluated and the results are illustrated in the graphs below. Handoff call prioritization is varied by changing the threshold values. Whilst keeping the basic bandwidth unit, and capacities constant.

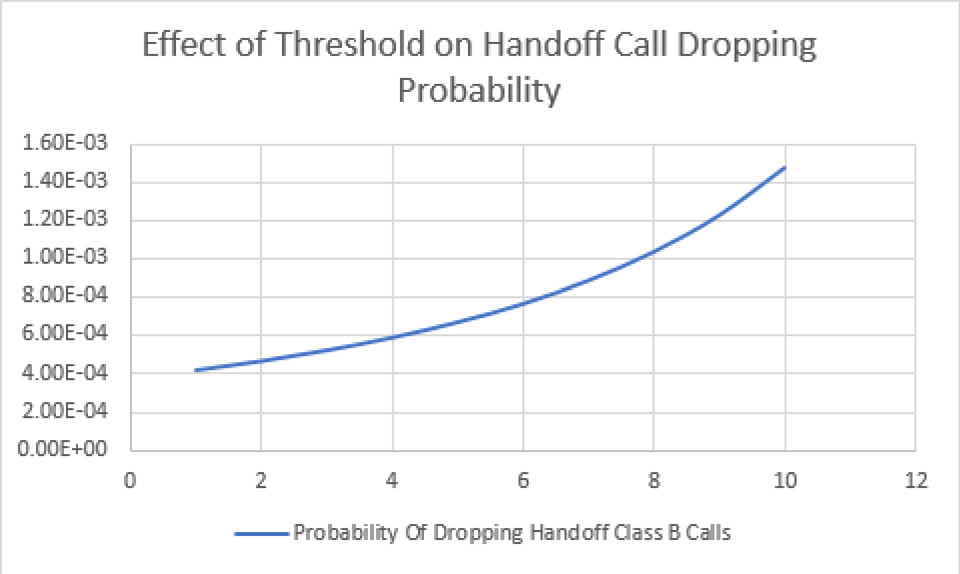

Figure 11: Effect of Threshold on Handoff Call Dropping Probability

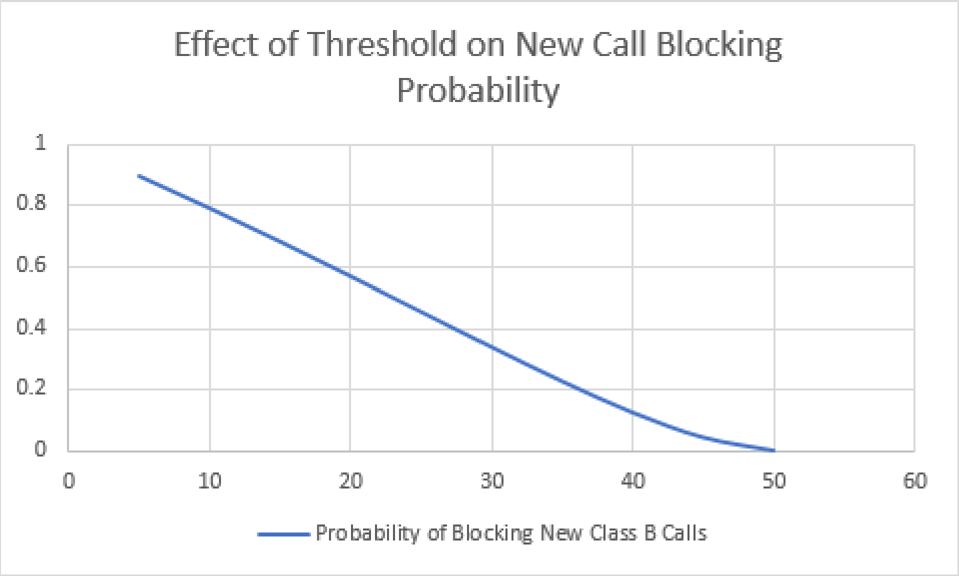

Figure 12: Effect of Threshold on New Call Blocking Probability

From the graphs above we can see that there is an increase in the handoff call dropping probability and a decrease in the new call blocking probability

Effect of increasing Basic Bandwidth Unit per call on Call Blocking/Dropping Probability.

The effect of increasing the basic bandwidth unit per call on new call blocking probability and handoff call dropping probability is evaluated and the results are illustrated on the graphs below. The basic bandwidth unit is varied whilst the capacity and threshold are kept constant.

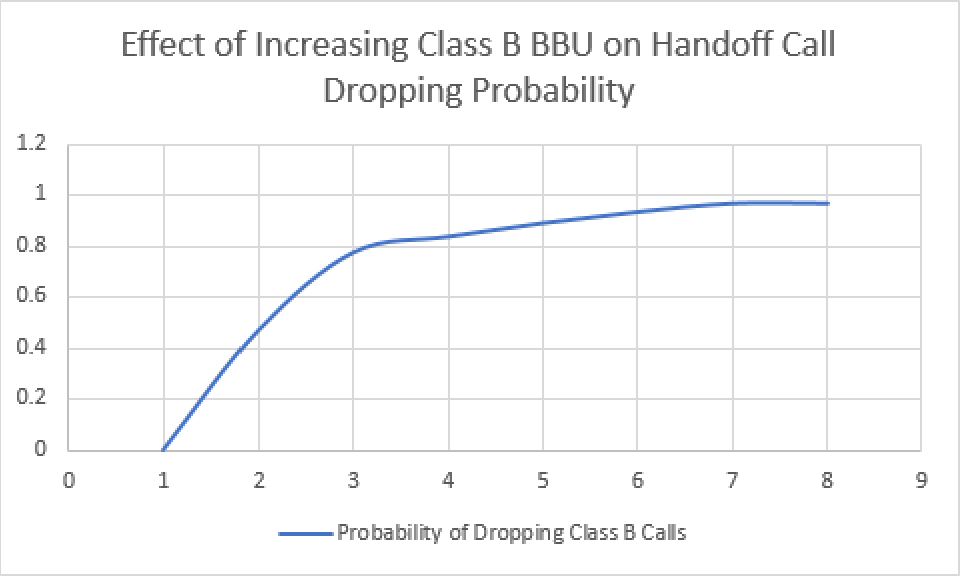

Figure 13: Effect of increasing BBU on Handoff Call Dropping Probability

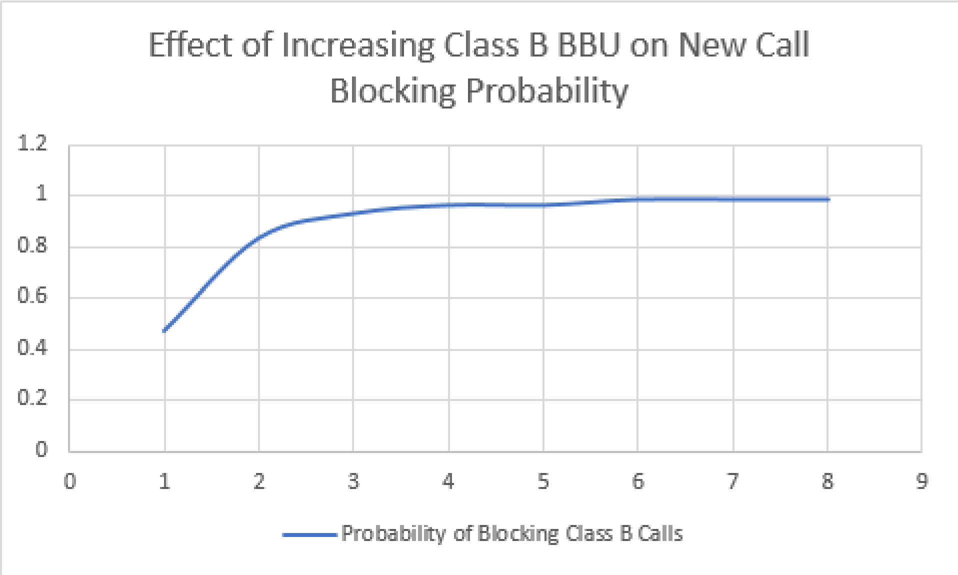

Figure 14: Effect of increasing BBU on new call blocking probability

From the above graphs we can see that there is an increase in both the call dropping and call blocking probabilities.

Discussion of Results

Effect of increasing call arrival rate.

From the graphs in figures 7 & 8 it can be seen that the call dropping and blocking probabilities increase when new call arrival rate is increased whilst other parameters like basic bandwidth unit, capacity and threshold were kept constant. This is because when the rate of call arrival is increased, the network capacity is unable to handle all the incoming new and handoff calls arriving thus the number of calls being blocked and dropped is increased thereby increasing the call blocking and dropping probability. The increases in the dropping probability is however less than that of new calls because handoff calls are prioritized over new calls hence more new calls are rejected compared to handoff calls

Effect of Increasing Network Capacity on Call Blocking/Dropping Probability.

From the graphs in figure 5 and 6, it can be seen that there is a decrease in the probability of dropping handoff calls when the network capacity is increased and from figure 5 and 7 it can be seen that there is an increase in the probability of blocking new calls when the capacity is increased. This is because when the capacity is being increased it is being increased for the handoff calls which means that handoff calls now occupy a bigger space in the available capacity thereby decreasing the space occupied by new calls. This then leads to the decrease in handoff call dropping probability and an increase in the new call blocking probability.

Effect of handoff call prioritization on Call Blocking/Dropping Probabilities.

From the graphs in figure 8 and 9 we can see that there is an increase in the dropping probability of handoff calls and from figure 8 and 10 we can see that there is a decrease in the blocking probability of new calls. This is because when handoff calls are prioritized, they are given more space on the available RAT capacity thus more handoff calls are accepted on the same number of admissible states thus the handoff call probability increases. The new call blocking probability decreases because when more space is allocated for handoff calls on the RAT capacity, less new calls are admitted on the same number of admissible states thus the new call blocking probability decreases.

Effect of increasing bbu Call Blocking/Dropping Probabilities.

Increasing the basic bandwidth unit of one type of call whilst maintaining the basic bandwidth unit of the other type of call resulted in increases in the dropping and blocking probabilities whilst the other dropping and blocking probabilities with a constant basic bandwidth unit decreased. This is because more resources are used by the call type with the varied basic bandwidth unit.

Conclusions

The following conclusions were derived from the results obtained in this report.

I. In the event that handoff calls are prioritized, the increase in the difference between dropping handoff calls and blocking new calls is directly proportional to the prioritization of handoff calls

II. When the basic bandwidth unit was increased, the limitations of the network as both the probability of dropping handoff calls and blocking new calls were increasing and they increased to a certain value where they stayed constant.

III. Increasing the rate of call arrival rate increased the call dropping and dropping probabilities showing that when more new calls arrive which is more than the network can take in then the call blocking and dropping probabilities increase.

These findings leads to the conclusion that when using Joint Call Algorithm Control to optimize the network one needs to carefully analyze the network requirements and must be willing to trade one advantage for the other for example in order to achieve low handoff call dropping probabilities one need to increase network capacity however this leads to an increase in the new call blocking probabilities thereby decreasing the quality of service of the network. In order to fully utilize the network resources, a network whereby the network resources are monitored and adjusted to meet the current demand needs to be built

Appendix.

Source Code.

The source code for this program can be found on my GitHub repository
https://github.com/tmuzanenhamo/Joint-Call-Admission-Control

```
/**
Joint Call Admission Control Algorithm for Heterogenous
Networks.
Tawanda Muzanenhamo
**/

import java.util.ArrayList;
import java.util.*;

public class Joint_Call_Algorithm{
   public static void main(String[] args){

   //Network specifications
   int c1 = 20; //RAT1 Capacity
   int c2 = 20; //RAT2 Capacity
   int t1 = 10; //RAT1 Threshold
   int t2 = 10; //RAT2 Threshold
   //basic bandwidth unit

   int bbu = 1;
   int bbu1 = 1;

   // Blocking and Dropping States Constants
   int admissible_states = 0;
   int class_A_newcall_blockingstate = 0;
   int class_A_handoff_droppingngstate = 0;
   int class_B_handoff_droppingstate = 0;
   int class_B_newcall_blockingstate = 0;

   ArrayList<ArrayList> admissable = new ArrayList<>();

   for (int m1 = 0; m1<t1+1; m1++ ){
       ArrayList<Integer> t = new ArrayList<>();
      for(int n1 = 2; n1<c1+1; n1++){
         for(int m2 = 0; m2<t2+1; m2++){
```

```
            for(int n2 = 0; n2<c2+1; n2++){
            if((m1 + n1 > c1) || (m2 + n2 > c2)){
                  break;
             }
             //Calculating the Blocking states
             if((bbu1+bbu1*(m1+n1)) > c1)
class_A_handoff_droppingngstate++;
             if((bbu1+bbu1*(m1+n1))> t1)
class_A_newcall_blockingstate++;
             if((bbu+bbu*(m1+n1) > c1) && (bbu+bbu*(m2+n2) >
c2 )) class_B_handoff_droppingstate++;
             if((bbu+bbu*( m1+n1) > t1) && (bbu+bbu*(m2+n2) >
t2)) class_B_newcall_blockingstate++;
             t.add(m1);
             t.add(n1);
             t.add(m2);
             t.add(n2);
             admissible_states ++;

            }

         }
      }
      admissable.add(t);


   }

   //printing the admissible states

   ArrayList<Integer> admissible_state = new ArrayList();
   for(ArrayList admissible_ : admissable){
            for(int i = 0; i <= admissible_.size()-1; i+=4){
                admissible_state.add((int)admissible_.get(i));

admissible_state.add((int)admissible_.get(i+1));

admissible_state.add((int)admissible_.get(i+2));

admissible_state.add((int)admissible_.get(i+3));
                System.out.print(admissible_state.toString()+"
");
                admissible_state.clear();
            }
```

```
            System.out.println();
        }

System.out.println("******************************************
**********************************");
    //Admissible state calculated value
    // Blocking and Dropping States Calculated Values
    System.out.println("Number of Admissable States :"+
admissible_states);
    System.out.println("Number of Blocking States for Class A
Handoff Calls :"+ class_A_handoff_droppingngstate);
    System.out.println("Number of Blocking States for Class A
New Calls :"+ class_A_newcall_blockingstate);
    System.out.println("Number of Blocking States for Class B
Handoff Calls :"+ class_B_handoff_droppingstate);
    System.out.println("Number of Blocking States for Class B
New Calls  :"+ class_B_newcall_blockingstate);

System.out.println("******************************************
**********************************");

   // Calculating Probabilities
    double Handoff_probA =
(double)(class_A_handoff_droppingngstate)/(double)(admissible_
states);
   // System.out.println(admissible_states);
    //System.out.println(class_A_handoff_droppingngstate);

//System.out.println((double)class_A_handoff_droppingngstate/(
double)admissible_states);
    double Newcall_probA =
(double)class_A_newcall_blockingstate/(double)admissible_state
s;
    double Handoff_probB =
(double)class_B_handoff_droppingstate/(double)admissible_state
s;
    double Newcall_probB =
(double)class_B_newcall_blockingstate/(double)admissible_state
s;

System.out.println("******************************************
**********************************");
    System.out.println("Blocking probability for class A
HandoffCalls :"+ Handoff_probA);
```

```
    System.out.println("Blocking probability for Class A
NewCalls :"+ Newcall_probA);
    System.out.println("Blocking probability for Class B
HandoffCalls :"+ Handoff_probB);
    System.out.println("Blocking Probability for Class B
NewCalls  :"+ Newcall_probB);

System.out.println("*******************************************
***********************************");




   }


}
```

New Call Arrival Rate Algorithm
The source code for the algorithm can be found here.
https://github.com/tmuzanenhamo/Joint-Call-Admission-Control

```
import math

def new_call(c1,c2,t1,bbu,t2,y):

   states = 0
   Ab = 0
   Ad = 0
   Bb = 0
   bd = 0

   n1 = 0
```

```
    n2 = 0
    m1 = 0
    m2 = 0

    dep = 1

    loading_new = y/dep
    loading_hand = 0.6*loading_new

    Prob = 0
    Prob_in = 0
    Prob_im = 0
    G = 0
    Blocking_probability_A =0
    Dropping_probability_A =0
    Blocking_probability_B =0
    Dropping_probability_B =0

    for n1 in range(0,t1+1):
        for m1 in range(0,c1+1):
            for n2 in range(0,t2+1):
                for m2 in range(0,c2+1):

                    ad_states = (((n1+m1)*bbu<= c1) and (n1*bbu<=t1) and ((n2+m2)*bbu <=c2) and
(n2*bbu<=t2))

                    blocking_state = (bbu + bbu*(n1+m1) > t1) and (bbu + bbu*(n2+m2)>t2)
                    dropping_state = (bbu +  bbu*(n1+m1) > c1) and (bbu + bbu*(n2+m2)>c2)

                    if(ad_states):
                        states = states+1
                        e= loading_new**(n1+n2)
                        f= loading_new**(m1+m2)
                        Prob_in = e*f
                        a = math.factorial(n1)
                        b = math.factorial(m1)
                        c = math.factorial(n2)
                        d = math.factorial(m2)

                        Prob_im = a*b*c*d

                        Prob = (Prob_in)/(Prob_im)
                        #nomalization factor
                        G = G + Prob

                        if(blocking_state):
                            Bb = Bb+1
                            Blocking_probability_B = Blocking_probability_B + Prob
```

```
                if(dropping_state):

                    Bd = Bd = 1

                    Dropping_probability_B = Dropping_probability_B + Prob

                if (bbu+(n1+m1)*bbu >t1):
                    Ab = Ab+1
                    Blocking_probability_A = Blocking_probability_A + Prob

                if (bbu + (n1+m1)*bbu >c1):
                    Ad =Ad+1
                    Dropping_probability_A = Dropping_probability_A + Prob
    print("The new call blocking probability for A is: ",Blocking_probability_A/G)
    print("The handoff call dropping probability for A is: ",Dropping_probability_A/G)
    print("The new call blocking probability for B is: ", Blocking_probability_B/G )
    print("The handoff call dropping probability for B is: ", Dropping_probability_B/G )

    return Blocking_probability_A/G, blocking_probability_B/G,   Dropping_probability_A/G,
Dropping_probability_B/G
   # print("Tawanda")




arr= []
Blocking_probability_A = []
Blocking_probability_B = []
Dropping_probability_A = []
Dropping_probability_B = []




for y in range(1,15,2):
    c1 = 20
    c2 = 20
    t1 = int(10)
    t2 = int(10)
    bbu = 1


Blocking_probability_A1,Dropping_probability_A1,Blocking_probability_B1,Dropping_proba
bility_B1 = new_call(c1,c2,t1,t2,bbu,y)
    Blocking_probability_A.append(Blocking_probability_A1)
    Blocking_probability_B.append(Blocking_probability_B1)
    Dropping_probability_A.append(Dropping_probability_A1)
```

```
Dropping_probability_B.append(Dropping_probability_B1)
arr.append(y)
```

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