**Introduction**

AHP (analytical hierarchical process) is an algorithm developed by Thomas.L.Saaty which is proved to be helpful in taking qualitative decisions regarding selection of the best alternative among the given ones respective of different criteria taken into consideration. In the assignment below ,we have used this process to select a best featured network from the given alternatives for the given service class on the basis of criteria – **access network type, roaming scenario and internet connectivity provided.** We have also used this process for choosing a priority of network types for each service class. The respective analysis performed and the code implemented will help our device to choose a best network (with respect to a service class) from the given ones. We have also taken into account other factors such as mobility and accessibility to support our analysis.

**Overview**

**What is vertical handover?**

Vertical handover or vertical handoff is a process in which network node changes the type of connectivity it uses to access a supporting infrastructure, usually to support node mobility. For example, a suitably equipped laptop might be able to use both a high speed wireless LAN and a cellular technology for Internet access. Wireless LAN connections generally provide higher speeds, while cellular technologies generally provide more ubiquitous coverage. Thus the laptop user might want to use a wireless LAN connection whenever one is available, and to 'fall over' to a cellular connection when the wireless LAN is unavailable. Vertical handovers refer to the automatic fall over from one technology to another in order to maintain communication.

Vertical handoffs between WLAN and UMTS have attracted a great deal of attention in all the research areas of the 4G wireless network, due to the benefit of utilizing the higher bandwidth and lower cost of WLAN as well as better mobility support and larger coverage of UMTS.

**Use Of AHP To Calculate Consistency**

**Short notations:**

**ANT**- access network type

**I**-internet connectivity provided

**R**-roaming scenari**o**

**Access network types**

**A1-** private network

**A2-** private network with guest access

**A3-** chargeable public network

**A4**- free public network

**C, S**-cost and security respectively

**CI**- consistency index

**CR**-consistency ratio

**Conversational class**

It is the service class with the highest QoS requirements including least transfer delay and time relation between information elements. This is the only scheme where the required characteristics are strictly given by human perception.

**E.g.: telephony speech, VoIP, video conferencing and other real time activities**.

**Assumptions**

* Security is more important than cost.
* The user is highly mobile.
* Internet connectivity is same for all network types.

**Assigning of weights to access network types**

**A1 is 9 times A4**: since we are assuming security to be more important so private network (A1) is preferred more than a free public network (A4)

**A1 is 7 times A3**: same reasoning as above but since chargeable public network tends to be more secured than a free public network so compared to a private network the latter(A3) is being provided with slightly more weight than former(A4).

**A1 is 3 times A2**: since A2 involves guest accounts so it is slightly less secured than A1.

**A2 is 5 times A3**: any private network is much more secured than any public network.

**A2 is 7 times A4**: same reason as above but A4 is given slightly less weight than A3.

**A3 is 2 times A4**: since both are public networks, so less secured but A3 is given slightly more weight than A4as chargeable public network tends to be more secured than a free public network.

**Calculation of consistency ratio**

A1 A2 A3 A4 priority vectors

A1 1 3 7 9 0.578

A2 1/3 1 5 7 0.295

A3 1/7 1/5 1 2 0.079

A4 1/9 1/7 1/2 1 0.048

**Principal Eigen value**= 4.177

**Consistency index**=0.059

**Consistency ratio**=0.066< 0.1

**Assignment of weights to the three benefit criteria**

**R is 3 times I:** since the user is highly mobile and delay sensitive applications require higher scenarios of roaming.

**R is 5 times ANT**: same reason as above but internet connectivity is given more weight than access network types for applications like video conferencing and VoIP.

**I is 2 times ANT**: as per the two reasons above, internet is slightly preferred over a choice of access network type.

**Calculation of consistency ratio**

I R ANT priority vector

I 1 1/3 2 0.230

R 3 1 5 0.648

ANT 1/2 1/5 1 0.122

**Principal Eigen value**= 3.0046

**Consistency index**=0.0023

**Consistency ratio**=0.0040< 0.1

**Security is 2 times Cost**: since we assumed that user is highly mobile and concerned about security so as to prevent the problems of jamming or intrusion through process like FHSS and Piggybacking.

S C priority vector

S 1 2 0.667

C 1/2 1 0.333

**Principal Eigen value**= 2.0

**Consistency index**=0.0

**Consistency ratio**=0.0< 0.1

**Streaming Class**

This scheme is one of the newcomers in data communication, raising a number of new requirements in both telecommunication and data communication systems. It is characterized by that the time relations (variation) between information entities (i.e. samples, packets) within a flow shall be preserved, although it does not have any requirements on low transfer delay. Acceptable delay variation is thus much greater than the delay variation given by the limits of human perception. **E.g.: streaming of audio and video.**

**Assumptions**

* Cost is more important than Security.
* Service is delay-insensitive.
* Internet connectivity is same for all network types.
* Private ANTs are chargeable.
* We are considering short streaming applications so user will not be highly mobile.
* Accessibility is also taken into account.

**Assigning of weights to access network types**

**A4 is 7 times A1**: since security is less important so any private network is much less preferred than a free public network.

**A4 is 4 times A2**: same reason as above but since A2 is more accessible than A1 so A2 is given slightly higher weight than A1 on comparison to A4.

**A4 is 4 times A3**: since cost is assumed to be more important.

**A3 is same as A2**: since both are offering chargeable access.

**A3 is 4 times A1**: since security is less important so any private network is much less preferred than any public network.

**A2 is 3 times A1**: since A2 at least offers guest access to continue streaming which A1 does not.

**Calculation of consistency ratio**

A4 A3 A2 A1 priority vectors

A4 1 4 4 7 0.587

A3 1/4 1 1 4 0.184

A2 1/4 1 1 3 0.168

A1 1/7 1/4 1/3 1 0.062

**Principal Eigen value**= 4.108

**Consistency index**=0.036

**Consistency ratio**=0.04< 0.1

**Assignment of weights to the three benefit criteria**

**I is 7 times R**: since delay variation is acceptable and good internet connectivity is of prime importance so as to maintain synchronization in transferred information entities.

**I is 4 times ANT**: as good internet connectivity is of prime importance but different classes of ANTs may restrict internet connectivity so ANT is given quite less weight than Internet connectivity.

**ANT is 2 times R**: as per our assumption seamless transition is not required for a less mobile user so Roaming is given slightly less weight than ANT.

**Calculation of consistency ratio**

I ANT R priority vector

I 1 4 7 0.715

ANT 1/4 1 2 0.187

R 1/7 1/2 1 0.098

**Principal Eigen value**= 3.0044

**Consistency index**=0.0022

**Consistency ratio**=0.0038< 0.1

**Cost is 4 times Security**: streaming audio and video applications do not require high security and at the same time cost for internet connectivity is to be considered.

C S priority vector

C 1 4 0.80

S 1/4 1 0.20

**Principal Eigen value**= 2.0

**Consistency index**=0.0

**Consistency ratio**=0.0< 0.1

**Interactive class**

When the end-user, that is either a machine or a human, is on line requesting data from remote equipment (e.g. a server), this scheme applies. Interactive traffic is the other classical data communication scheme that on an overall level is characterized by the request response pattern of the end-user. At the message destination there is an entity expecting the message (response) within a certain time. Round trip delay time is therefore one of the key attributes. Another characteristic is that the content of the packets shall be transparently transferred (with low bit error rate).

**E.g.: web browsing, server access.**

**Assumptions**

Cost is more important than Security but it is slightly more important than streaming class.(for services like using email accounts and social media)

* We are considering general web browsing.
* Service should be of low bit error rate.
* Internet connectivity is same for all network types.
* Private ANTs are chargeable.
* Accessibility is also taken into account.

**Assigning of weights to access network types**

**A4 is 7 times A1**: since cost is assumed to be more important so a free public network is highly preferred over any kind of restrictive private network.

**A4 is 3 times A2**: same reason as above but since A2 is more accessible than A1 so A2 is given slightly higher weight than A1 on comparison to A4.

**A4 is 4 times A3**: since cost is assumed to be more important (as accessibility and security issues are comparable for both A4 and A3).

**A2 is 2 times A3**: since security is slightly important in this class, so A2 is given slightly more weight than A3.

**A2 is 2 times A1**: since in terms of cost and security A2 and A1 are assumed to be same but in terms of accessibility A2 is slightly preferred to A1.

**A3 is 2 times A1**: in terms of cost A3 and A1 are assumed to be same and A1 is highly restrictive in comparison to A3, so A3 is slightly preferred over A1.

**Calculation of consistency ratio**

A4 A2 A3 A1 priority vectors

A4 1 3 4 7 0.574

A2 1/3 1 2 2 0.207

A3 1/4 1/2 1 2 0.136

A1 1/7 1/2 1/2 1 0.083

**Principal Eigen value**= 4.092

**Consistency index**=0.031

**Consistency ratio**=0.034< 0.1

**Assignment of weights to the three benefit criteria**

**I is 8 times R**: since higher scenarios of roaming are not needed and good internet connectivity is of prime importance for browsing , so internet connectivity is highly preferred over Roaming

**I is 5 times ANT**: as good internet connectivity is required but different classes of ANTs may restrict internet connectivity so ANT is given less weight than Internet connectivity.

**ANT is 2 times R**: since higher scenarios of roaming are less considered so Roaming is given slightly less weight than ANT.

**Calculation of consistency ratio**

I ANT R priority vector

I 1 5 8 0.750

ANT 1/5 1 2 0.162

R 1/8 1/2 1 0.087

**Principal Eigen value**= 3.00375

**Consistency index**=0.00188

**Consistency ratio**=0.00323< 0.1

**Cost is 2 times Security**: general web browsing requires security but at the same time cost for internet connectivity is of prime importance.

C S priority vector

C 1 2 0.667

S 1/2 1 0.333

**Principal Eigen value**= 2.0

**Consistency index**=0.0

**Consistency ratio**=0.0< 0.1

**Background class**

When the end-user, that typically is a computer, sends and receives data-files in the background, this scheme applies. Background traffic is one of the classical data communication schemes that on an overall level is characterized by that the destination is not expecting the data within a certain time. The scheme is thus more or less delivery time insensitive. **Eg: background downloading of mails, sending of SMSs over the internet.**

**Assumptions**

* Cost is slightly more important than security.
* Internet connectivity is same for all network types.
* Private ANTs are chargeable.
* Accessibility is taken into consideration.
* Assigning of weights to access network types

**A4 is 9 times A1**: as private network is costly and restrictive.

**A4 is 7 times A2**: same reason as above but A2 is less restrictive than A1.

**A4 is 5 times A3**: both are public networks but A3 is chargeable.

**A3 is 3 times A1**: private networks with no guest access are highly restrictive, though cost-wise these two may be the same.

**A3 is 2 times A2**: in terms of cost A3 and A2 are assumed to be same but a private network is more restrictive than a public network.

**A2 is 2 times A1**: since in terms of cost A2 and A1 are assumed to be same but in terms of accessibility A2 is slightly preferred to A1.

Calculation of consistency ratio

A4 A3 A2 A1 priority vectors

A4 1 5 7 9 0.672

A3 1/5 1 2 3 0.169

A2 1/7 1/2 1 2 0.100

A1 1/9 1/3 1/2 1 0.059

**Principal Eigen value**= 4.067

**Consistency index**=0.022

**Consistency ratio**=0.025< 0.1

**Assignment of weights to the three benefit criteria**

**I is 5 times R**: since higher scenarios of roaming are not needed and good internet connectivity is required for downloading, so internet connectivity is preferred over Roaming

**I is 3 times ANT**: as good internet connectivity is required but different classes of ANTs may restrict internet connectivity so ANT is given less weight than Internet connectivity.

**ANT is 2 times R**: since higher scenarios of roaming are of lesser importance so Roaming is given slightly less weight than ANT.

**Calculation of consistency ratio**

I ANT R priority vector

I 1 3 5 0.648

ANT 1/3 1 2 0.230

R 1/5 1/2 1 0.122

**Principal Eigen value**= 3.0046

**Consistency index**=0.0023

**Consistency ratio**=0.004 < 0.1

**Cost is 2 times Security**: downloading does not require much security and cost for internet connectivity is the main constraint.

C S priority vector

C 1 2 0.667

S 1/2 1 0.333

**Principal Eigen value**= 2.0

**Consistency index**=0.0

**Consistency ratio**=0.0< 0.1

Java Class to find ranked list of available networks

public class Calculate\_ntw

{

private int num\_of\_ntw;

private int srv\_class;

private double[][] ant = {{0.578,0.295,0.079,0.048},

{0.062,0.168,0.184,0.587},

{0.083,0.207,0.136,0.574},

{0.059,0.1,0.169,0.672}};

private double[][] ari\_cs = {{.122,.648,.230,.33333,.66667},

{.187,.098,.715,.8,.2},

{.162,.087,.75,.66667,.33333},

{.230,.122,.648,.666667,.33333}};

private double[][] ntw ;

public Calculate\_ntw(int n,int sc)

{

num\_of\_ntw = n;

srv\_class = sc;

}

public void set\_ntw(double[][] x)

{

ntw = x;

}

public double[][] do\_it()

{

int i,j;

int x;

for(i=0;i<num\_of\_ntw;i++)

{

x = (int)ntw[i][0];

ntw[i][0] = ant[srv\_class-1][x-1];

}

//replaced ant values

double[][] a = new double[num\_of\_ntw][num\_of\_ntw];

double[][] r = new double[num\_of\_ntw][num\_of\_ntw];

double[][] ic = new double[num\_of\_ntw][num\_of\_ntw];

double[] cpb = new double[num\_of\_ntw];

double[][] sec = new double[num\_of\_ntw][num\_of\_ntw];

double[] a\_cs = new double[num\_of\_ntw];

double[] r\_cs = new double[num\_of\_ntw];

double[] ic\_cs = new double[num\_of\_ntw];

double[] sec\_cs = new double[num\_of\_ntw];

double[] a\_pv = new double[num\_of\_ntw];

double[] r\_pv = new double[num\_of\_ntw];

double[] ic\_pv = new double[num\_of\_ntw];

double[] sec\_pv = new double[num\_of\_ntw];

double Z = 3.00000;

double temp,temp\_indx;

double[] ben = new double[num\_of\_ntw];

double[][] ben\_sort = new double[num\_of\_ntw][2];

double sum=0.000;

for(i=0;i<num\_of\_ntw;i++)

{

sum+=ntw[i][3];

}

for(i=0;i<num\_of\_ntw;i++)

{

cpb[i]=ntw[i][3]/sum;

}

for(i=0;i<num\_of\_ntw;i++)

{

for(j=0;j<num\_of\_ntw;j++)

{

a[i][j]= ntw[i][0]/ntw[j][0];

r[i][j]= ntw[i][1]/ntw[j][1];

ic[i][j]= ntw[i][2]/ntw[j][2];

sec[i][j]= ntw[i][4]/ntw[j][4];

}

}

//initialised matrices for 1st 3 criterion

for(i=0;i<num\_of\_ntw;i++)

{

a\_cs[i]=0;

r\_cs[i]=0;

ic\_cs[i]=0;

sec\_cs[i]=0;

a\_pv[i]=0;

r\_pv[i]=0;

ic\_pv[i]=0;

sec\_pv[i]=0;

ben[i]=0;

}

//initialised column sum matrices & priority vector matrices & benefit matrix to zero

for(i=0;i<num\_of\_ntw;i++)

{

for(j=0;j<num\_of\_ntw;j++)

{

a\_cs[i]+= a[j][i];

r\_cs[i]+= r[j][i];

ic\_cs[i]+= ic[j][i];

sec\_cs[i]+= sec[j][i];

}

}

// found column sums

for(i=0;i<num\_of\_ntw;i++)

{

for(j=0;j<num\_of\_ntw;j++)

{

a[j][i] = a[j][i]/a\_cs[i];

r[j][i] = r[j][i]/r\_cs[i];

ic[j][i] = ic[j][i]/ic\_cs[i];

sec[j][i] = sec[j][i]/sec\_cs[i];

}

}

//normalised matrices

for(i=0;i<num\_of\_ntw;i++)

{

for(j=0;j<num\_of\_ntw;j++)

{

a\_pv[i]+= (a[i][j]/Z);

r\_pv[i]+= (r[i][j]/Z);

ic\_pv[i]+= (ic[i][j]/Z);

sec\_pv[i]+= (sec[i][j]/Z);

}

}

//found normalised priority vectors

for(i=0;i<num\_of\_ntw;i++)

{

ben[i]= ben[i]+(a\_pv[i]\*ari\_cs[srv\_class-1][0]);

ben[i]= ben[i]+(r\_pv[i]\*ari\_cs[srv\_class-1][1]);

ben[i]= ben[i]+(ic\_pv[i]\*ari\_cs[srv\_class-1][2]);

}

//found relative ranking of networks with respect to 1st 3 criteria

for(i=0;i<num\_of\_ntw;i++)

{

ben[i] += ben[i]\*((sec\_pv[i]\*ari\_cs[srv\_class-1][4])-(cpb[i]\*ari\_cs[srv\_class-1][3]));

}

//found final relative ranking of networks

for(i=0;i<num\_of\_ntw;i++)

{

ben\_sort[i][0]= i+1;

ben\_sort[i][1]= ben[i];

}

for(i=1;i<num\_of\_ntw;i++)

{

temp = ben\_sort[i][1];

temp\_indx = ben\_sort[i][0];

j=i-1;

while(j>=0 && ben\_sort[j][1]<temp)

{

ben\_sort[j+1][1]=ben\_sort[j][1];

ben\_sort[j+1][0]=ben\_sort[j][0];

j--;

}

ben\_sort[j+1][1]=temp;

ben\_sort[j+1][0]=temp\_indx;

}

//produced sorted list of networks

return ben\_sort;

}

}

**Explanation of the Code:**

It takes number of networks, current service class & network parameters as inputs from the GUI. The weights of the criteria – access network type(ANT), roaming(R) , internet connectivity(IC), cost(C) & security(S) as well as the weights of each ANT are fixed & the values obtained in the report are used.

The code replaces the values of the access network types from 1,2,3,4 to normalized priority vector values for ANT. The ranking priority vectors of the input networks in each of the 5 criteria are found.

Then the ranking priority vector (NX1) of the networks as per ANT, R, IC are obtained by the method of matrix multiplication of the 2 matrices (NX3 & 3X1). Let us consider there are 3 networks & the initial benefit priority vector is {ben1, ben2, ben3}. To account for cost & security as well, we have used the following formula in the code:

ben1\_final = ben1 \* (1 + S1\*(wt. of security) – C1\*(wt. of cost))

ben2\_final = ben2 \* (1 + S2\*(wt. of security) – C2\*(wt. of cost))

ben3\_final = ben3 \* (1 + S3\*(wt. of security) – C3\*(wt. of cost))

**Note:** The code has been developed in both command line and GUI mode. The java classes which are used to take user input in these 2 cases will be presented in the final presentation.

**Conclusion**

For all the four classes mentioned in the assignment, the respective matrices for access network types and matrices for comparison of three criteria – access network type, internet connectivity provided and roaming scenario are found to be consistent as per the method of analytical hierarchical processing.

As the specifications for all the classes are different and different networks existing in the vicinity provide different kinds of services, based on the above procedure, the device itself will select the best featured network.