International Journal of Hybrid Information Technology
Vol.7, No.1 (2014), pp.25-42
http://dx.doi.org/10.14257/ijhit.2014.7.1.03

A Novel Mechanism on Network Selection for Fourth Generation Communication Networks

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Abstract

In a heterogeneous networking environment of Fourth Generation communication technology, there will have a coexistence of different radio access technologies to serve the user. The users will always try to get the best service from the heterogeneous network. So selection of best access network at a particular time will be problematic and challenging. There will be a conflict between the network technologies of a heterogeneous networking system. We have taken into account the influence of some factors on which the selection of best access network will depend. Also, we have tried to solve the network selection problem by using Game theoretical concept. By using the concept of strategy space, quality points and weighting factors in the game theoretical model, a mathematical way for selecting the best network is demonstrated. The paper introduces the concept of optimum network selection mechanism from any number of competing networks. Lastly it is shown that the best connected networking system can always be possible in 4G communication network using this network selection mechanism efficiently.

Keywords*: 4G heterogeneous communication networks, game theory, network selection, quality points, strategy space, payoffs, drainage rate*

1. Introduction

The communication technology is developing very fast. The total communication system in general is divided into 1st to 4th generation. The communication networking system up to third generation (3G) is homogeneous. So there needs no selection of network or there are no options at all. In future generation wireless access networks, the users will have the chance of choosing among multiple connectivity opportunities provided by different access networks [1]. In fourth generation (4G) [2], the networking system is heterogeneous .A lot of network technologies are combined to create a communication networking system. Actually, the advantages of different networks are combined to provide the best service to the users. This kind of network is defined as heterogeneous network. So selection of best network to serve the user at any instant from a heterogeneous networking system is needed as there are a lot of options. The phenomenon is illustrated in Figure1.

ISSN: 1738-9968 IJHIT

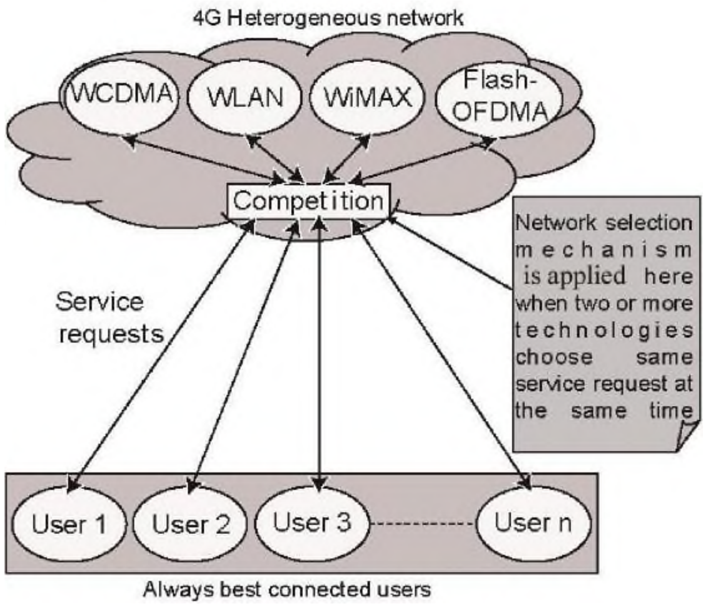


Figure 1. Interaction between the users and 4G Heterogeneous Network

Best network selection from such a heterogeneous network in 4G communication networks has become an important topic of research. Various research papers on network selection have already been published [3- 9]. In a typical paper on network selection mechanism for 4G [3], the authors have described a way to select the best access technology from a heterogeneous network combining three technologies. But the mechanism to select an optimum network technology from a heterogeneous network consisting of more than three technologies was beyond the scope of that work. The work of J. Antoniou *et al.*, [4] is about selection of best network from a converged 4G networking system by Game theory. "A game theoretic approach for network selection" [5] is much effective in this field. The work of A. Kaloxylos *et al.*, [6] deals with network selection mechanism from a heterogeneous wireless network. V. Gazis *et al.*, [7] gives us a good idea about 4 G mobile communication systems. Location Based QoS-Aware Network Selection Mechanism for the Nomadic Mobile Services [8] has useful data for increasing QoS. The research paper of R. V. Eijk *et al.*, [9] is about Access Network Selection in a 4G Environment. To know about the evolution of different generations, the research paper named by "2G-4G Networks: Evolution of Technologies, Standards, and Deployment" [10] is tremendous. There are also a lot of works related to 4G communication networks which are not mentioned here. The concept of Game Theory [1113] is used extensively in these research papers. In this paper we have shown the complete way to select the best network from a heterogeneous network of 4G combining any number of technologies. The mechanism tells us the way to select the best network at any instant. The Game theoretic approach is used to select the best network. Introduction of strategy space, weighting factor and quality point makes it easier to select the best network. A heterogeneous network combining four different networking technologies (WCDMA, WLAN, WiMAX & Flash-OFDM) and four services (streaming video, Internet surfing, Voice call, HDTV) against them is taken as an example. The selection of a particular network to serve an individual service to the user depends on a number of factors. This work targets to take into account these factors and their influences in the selection of best network. Five possible factors are taken into account to hunt the best network. The properties of the individual network technologies are verified and compared based on the five factors. All the factors related to the selection of best network are easily computable for a heterogeneous network consisting of four technologies. But computation of one of the five factors called drainage rate of batteries [14] seems to be quite difficult when the numbers of network technologies are greater than four. Because a lot of combinations for drainage rate are possible for such an increased number of technologies and it is not so easy to compute drainage rate for every single combination dynamically. We have succeeded to overcome this difficulty by computing drainage rate directly or statically using a simple equation which is described in section 6 of this paper.

Finally a mechanism is implemented to select a best network from a heterogeneous network combining any number of networks. By using this network selection mechanism efficiently, a relatively congestion [15] free best connected [16] networking system can always be possible in 4G. Most importantly, a network provider's main view is to improve the QoS for the consumers. Improvement of QoS can also be possible by using this network selection mechanism.

2. Game Theory

Game Theory provides appropriate models and tools to handle multiple, interacting entities attempting to make decision and seeking a solution state that maximizes each entity's utility [5]. Game theory can be defined as the study of a mathematical model of conflict and co-operation between intelligent rational decision makers [11].

Game theory is the formal study of conflict and cooperation. Game theoretic concepts apply whenever the actions of several agents are interdependent. These agents may be individuals, groups, firms or any combination of these. The concepts of game theory provide a language to formulate structure, analyze, and understand strategic scenarios.

More specifically game theory can be defined as a distinct and interdisciplinary approach to the study of human behavior. The disciplines most involved in game theory are mathematics, economics and the other social and behavioral sciences. [12]

Game Theory has been extensively used in networking research as a theoretical decision-making framework, *i.e.*, for routing, congestion control [15] resource sharing etc. The Network Selection [3, 6] decision may benefit from such a theoretical framework that considers decision-making, interacting entities.

3. Our Proposed Mechanism

Game theory is used by us to select the best network from a 4G communication network. To do so, let us consider the following game:
Four network technologies are used here (4 players)

1. WCDMA P1 (player 01)
2. WLAN P2 (player 02)
3. WiMAX P3 (player 03)
4. Flash-OFDM P4 (player 04) And

four services against them (4 Strategies)

1. Video streaming 1 (strategy 01)
2. Internet surfing 2 (strategy 02)

3. Voice call 3 (strategy 03)

4. HDTV 4 (strategy 04)

Let,

G= {N, K, P_i} [3]

Where,

N= A set of players= {WCDMA (P1), WLAN (P2), WiMAX (P3), Flash OFDM (P4)}

K= A set of service requests that the access network is going to serve (Strategy).

P_i= payoff of each player P for choosing a strategy from set K. The strategy space is describing in the next section.

3.1 Strategy space

In this section, a new concept called “strategy space” is introducing. Following are the elements that make up the strategy space:

a) **Individual access network:** According to a Game theoretic model [4], the players of the game are the individual access network (in our work WCDMA,WLAN,WiMAX,& flash-OFDM).Each of which compete to win a service request .

b) **Strategies that access networks can take:** In a Game theoretic model each player can choose a strategy from a set of strategies. In a network selection oriented game, the strategies are the service requests. At a particular time each player makes choice of a strategy with the aim of achieving highest payoff. In this work each network technology makes choice of a service request with this aim. Therefore there are varying combinations of these strategies which give the strategy space co-ordinates. At any instant of time each of the player choose a strategy and thus the strategy space formed. For example, by the co-ordinate (1,1,1,2) we mean that WCDMA,WLAN & WiMAX networks have chosen the same strategy, that is strategy 1 (Streaming video) and flash-OFDM has chosen strategy 2(Internet surfing). Our model says that, the Game will be played between the three players (WCDMA , WLAN & WiMAX) since they make choice of the same strategy but flash-OFDM will not have to compete the Game because it has no competitor at that moment and can serve with its chosen strategy . Finally, the payoffs of the competing networks are computed and the network with the highest payoffs wins to serve the chosen strategy in that particular time.

4. Calculation

4.1 Influencing factors

According to the approach of this work, the payoffs of the network are influenced by some input factors. These inputs are considered in this work to compute payoffs. These are as follows:

a) **The type of services---**Streaming Video (1), Internet surfing (2), Voice call (3), HDTV (4)

b) **User preference** Cost (1), Quality (2)

c) **State of network (traffic)** Dense (1), Medium (2), Free (3)

d) **Speed of the user** High speed (1), Low speed (2), Stable (3)

e) **Drainage rate of battery** (1),(2),(3),(4),(5),(6),(7),(8),(9),(10) .... (24).

The input factors can also be calculated dynamically .The fifth factor (drainage rate) is dynamic here.

Let us clarify the concept of this factor. In this work, the authors have considered a user equipment or device which can operate in four modes: WCDMA, WLAN, WiMAX, and flash-OFDM. The drainage rate of battery power is specific for each mode. The drainage rate of battery depends on a lot of factors which are not considered in this work. So, dynamic factor means that the 4G core network will collect real time information regarding the drainage rate of battery at four mentioned modes. Therefore the drainage rate of battery as well as the fifth factor can be explained by the following ways:

1. WCDMA>WLAN>WiMAX>Flash-OFDM

This means that, WCDMA has the least rate (Battery power remains for long time) & flash-OFDM has the highest drainage rate of battery power. (Battery power lost within a short time) when input condition 01 is selected.

In the same way, the other combinations for input condition 2, 3 and so on can be represented as follows:

2.WCDMA>WLAN>Flash-OFDM>WiMAX
3.WCDMA>WiMAX>WLAN>Flash-OFDM
4.WCDMA>WiMAX>Flash-OFDM>WLAN
5. WCDMA>Wi-Fi> WLAN >WiMAX
6.WCDMA>Flash-OFDM>WiMAX>WLAN
7.WLAN>WCDMA>WiMAX>Flash-OFDM
8.WLAN>WCDMA>Flash-OFDM>WiMAX
9.WLAN>WiMAX>WCDMA>Flash-OFDM
10.WLAN>WiMAX>FlashOFDM>WCDMA
11.WLAN>Flash-OFDM>WCDMA>WiMAX
12.WLAN>Flash-OFDM >WiMAX>WCDMA
13.WIMAX>WCDMA>WLAN> Flash-OFDM
14.WIMAX>WCDMA>Flash-OFDM >WLAN
15. WIMAX>WLAN>WCDMA> Flash-OFDM
16.WIMAX>WLAN> Flash-OFDM >WCDMA
17.WIMAX> Flash-OFDM >WCDMA>WLAN
18.WIMAX> Flash-OFDM >WLAN>WCDMA
19. Flash-OFDM >WCDMA>WLAN>WiMAX
20. Flash-OFDM >WCDMA>WiMAX>WLAN
21. Flash-OFDM >WLAN>WCDMA>WiMAX
22. Flash-OFDM >WLAN>WiMAX>WCDMA
23. Flash-OFDM >WiMAX>WCDMA>WLAN
24. Flash-OFDM >WiMAX>WLAN>WCDMA

4.2 Assignment of quality points

Every network technology in 4G may have advantages & disadvantages over another network technology in different situations. These advantages and disadvantages have been interpreted mathematically by a point defined as quality Point. The quality points to each player (Network) based on the above mentioned five factors are assigned by the following way. Here,

WCDMA is player 1(P1)

WLAN is player 2(P2)

WiMAX is player 3 (P3)

Flash-OFMD is player 4(P4).

A) Based on input1 (Type of service)

A1.When input 1=1(streaming video)

Quality point for four players -----

Qp1, in1=1=3 Qp2, in1=1=5 Qp3, in1=1=6 Qp4, in1=1=7

A2.When input 1=2(internet surfing)

Quality point for four players---------

Qp1, in1=2=3 Qp2, in1=2=4 Qp3, in1=2=4 Qp4, in1=2=5

A3.When input 1=3(voice call)

Quality points for four players -------

Qp1, in1=3=7 Qp2, in1=3=4 Qp3, in1=3=4 Qp4, in1=3=3

A4. When input 1=4(HDTV)

Quality points for four players -------

Qp1, in1=4=7 Qp2, in1=4=5 Qp3, in1=4=4 Qp4, in1=4=4

B. Based on input 2(user preference)

B1.When input 2=1(cost: i.e. the user prefers cost to quality):

Quality points for four players -----

Qp1, in2=1=3 Qp2, in2=1=7 Qp3, in2=1=4 Qp4, in2=1=4

B2. When input 2=2(Quality: i.e. the user prefers Quality to cost):

Quality points for four players -----

Qp1, in2=2=3 Qp2, in2=2=5 Qp3, in2=2=6 Qp4, in2=2=7

C. Based on input 3(state of the network):

C1.When input 3=1(network traffic is dense)

Quality points for four players -------

Qp1, in3=1=0 Qp2, in3=1=0 Qp3, in3=1=0 Qp4, in3=1=1

C2. When input 3=2(network traffic is medium)

Quality points for four players -------

Qp1, in3=2=7 Qp2, in3=2=3 Qp3, in3=2=5 Qp4, in3=2=8

C3.when input 3=3(network traffic is free)

Quality points for four players -------

Qp1, in3=3=4 Qp2, in3=3=7 Qp3, in3=3=4 Qp4, in3=3=8

D. Based on input 4(speed of user)

D1.when input 4=1(high speed)

Quality points for four players -------

Qp1, in4=1=5 Qp2, in4=1=0 Qp3, in4=1=7 Qp4, in4=1=8

D2.when input 4=2(low speed)

Quality points for four players------

Qp1, in4=2=6 Qp2, in4=2=1 Qp3, in4=2=7 Qp4, in4=2=8

D3.when input 4=3(static user)

Quality points for four players------

Qp1, in4=3=3 Qp2, in4=3=7 Qp3, in4=3=3 Qp4, in4=3=4

E. Based on input5 (Drainage Rate of Battery)

E1.When input5=1(WCDMA>WLAN>WiMAX> Flash-OFDM)

Quality points for four players-----

Qp1, in5=1=7 Qp2, in5=1=5 Qp3, in5=1=3 Qp4, in5=1=2

E2.When input5=2(WCDMA>WLAN> Flash-OFDM >WiMAX)

Quality points for four players-----

Qp1, in5=2=7 Qp2, in5=2=5 Qp3, in5=2=2 Qp4, in5=2=3

E3.When input5=3(WCDMA>WiMAX>WLAN> Flash-OFDM)

Quality points for four players-----

Qp1, in5=3=7 Qp2, in5=3=3 Qp3, in5=3=5 Qp4, in5=3=2

E4.When input5=4(WCDMA>WiMAX> Flash-OFDM >WLAN)

Quality points for four players-----

Qp1, in5=4=7 Qp2, in5=4=2 Qp3, in5=4=5 Qp4, in5=4=3

E5.When input5=5(WCDMA> Flash-OFDM > WLAN >WiMAX)

Quality points for four players-----

Qp1, in5=5=7 Qp2, in5=5=3 Qp3, in5=5=2 Qp4, in5=5=5

E6.When input5=6(WCDMA> Flash-OFDM >WiMAX>WLAN)

Quality points for four players-----

Qp1, in5=6=7 Qp2,in5=6=2 Qp3,in5=6=3 Qp4, in5=6=5

E7.When input5=7(WLAN>WCDMA>WiMAX> Flash-OFDM)

Quality points for four players-----

Qp1, in5=7=5 Qp2, in5=7=7 Qp3, in5=7=3 Qp4, in5=7=2

Similarly quality points for the other combinations can be assigned depending on the condition of those combinations.

The quality point for each factor used in this work can be static or dynamic. They are not necessarily fixed. Depending on various properties of the network, they can be rearranged. The authors have just shown a mathematical method of network selection decision. The quality points used here are based on assumption and one can take these as example.

4.3 Weighting factors

One can easily understand that the five factors have considered in this work are not equally important. Some are more important and the others are less. Therefore, the weighting factors are used to interpret this effect. The weighting factors are considered as follows:

W_A= weighting factor for input A (Type of service) =20

W_B= weighting factor for input B (User preference) =30

W_C= weighting factor for input C State of the network) =50

W_D= weighting factor for input D (Speed of the User) =40

W_E= weighting factor for input E (Drainage rate of battery) =35

The weighting factors used here are based on assumption and one can take these as example. Depending on various properties of the network, they can be rearranged logically.

4.4 Calculating payoffs

The payoff of each network is the weighted sum of the quality points which a network obtains from the five inputs. Therefore, the following equation can be used to calculate the payoffs of the networks.

$$P_i = W_A Q_A + W_B Q_B + W_C Q_C + W_D Q_D + W_E Q_E \ldots (01)$$ [3]

Here,

i = 1(WCDMA), 2(WLAN), 3(WiMAX), 4(Flash-OFDM)

Q_A, QB ...QE are the quality points obtained by the players from inputs ranging from A to E.

W_A, W_B, ... W_E are the weighting factors for inputs ranging from A to E.

Equation (01) can be written separately for 4 players as:

$$P_{1\ (WCDMA)} = W_A Q_{A1} + W_B Q_{B1} + W_C Q_{C1} + W_D Q_{D1} + W_E Q_{E1} \ldots (02)$$

$$P_{2\ (WLAN)} = W_A Q_{A2} + W_B Q_{B2} + W_C Q_{C2} + W_D Q_{D2} + W_E Q_{E2} \ldots (03)$$

$$P_{3\ (WiMAX)} = W_A Q_{A3} + W_B Q_{B3} + W_C Q_{C3} + W_D Q_{D3} + W_E Q_{E3} \ldots. \ (04)$$

$$P_{4\ (Flash\text{-}OFDM)} = W_A Q_{A1} + W_B Q_{B1} + W_C Q_{C1} + W_D Q_{D1} + W_E Q_{E1} \ldots.. \ (05)$$

4.5 The network selection decision

Using the above four equations ,one can get the payoff for each network and the network with the highest payoff will serve a particular service request of the user in case two or three or four networks (players) make choice of the same service request (strategy) at the same time. In that case, each network technologies want to build up a highest payoff for which they need to maximize their quality points. As an output of that action the users always get the best service from the heterogeneous network. So, always best connected networking system is developed. If the requested services are different for the four networks then the payoff calculation is not needed as there is no completion. A relatively congestion free network is also developed.

4.6 Flow chart for network selection process

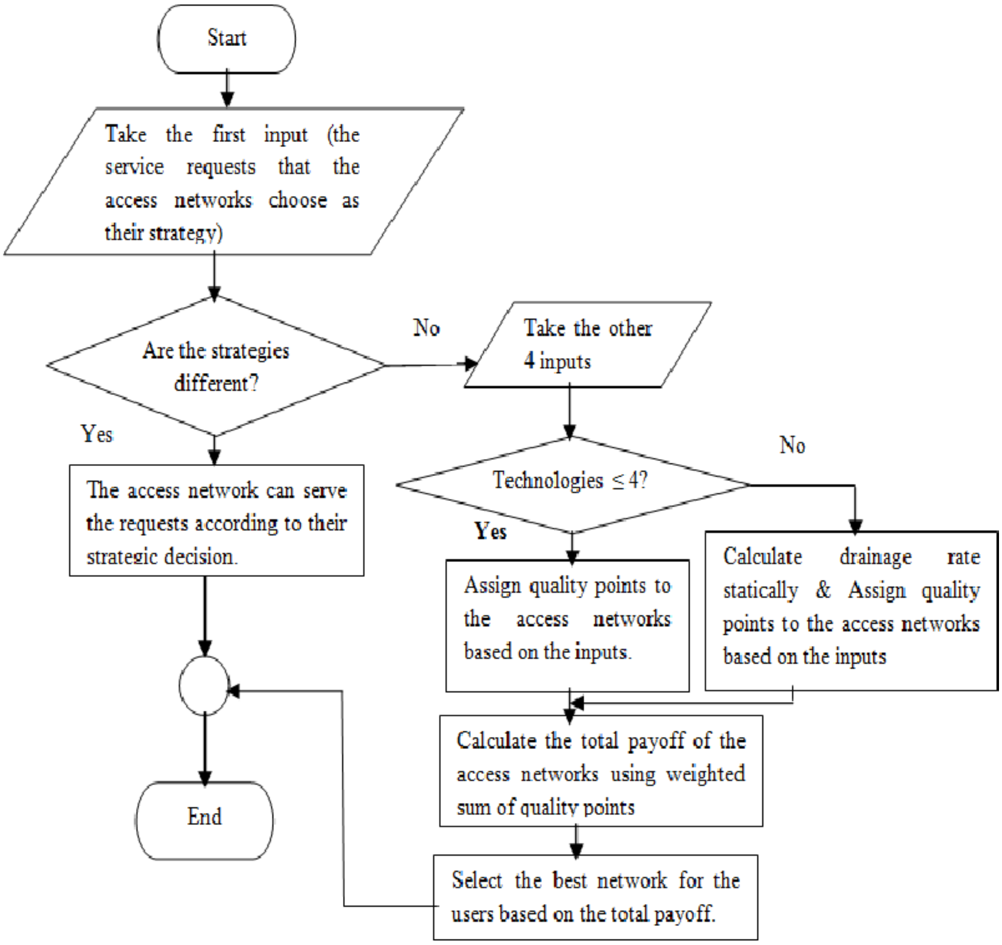


Figure 2. Network selection process

5. The Implementation and Proof of the Mechanism

The implementation of the network selection mechanism is done by using C++ programming language. The program takes the values of all inputs that are described before. Calculation of payoffs is also done by using the program. The payoffs for different networks are then compared to decide which network is best. Finally the optimum network is selected by this program. Some examples of the result are described below to clarify the whole process of the mechanism.

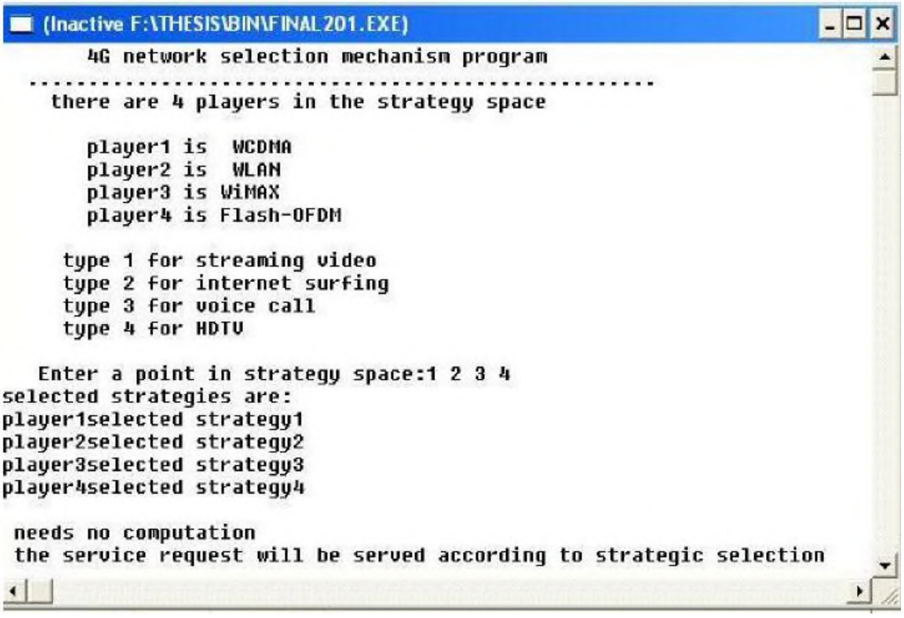
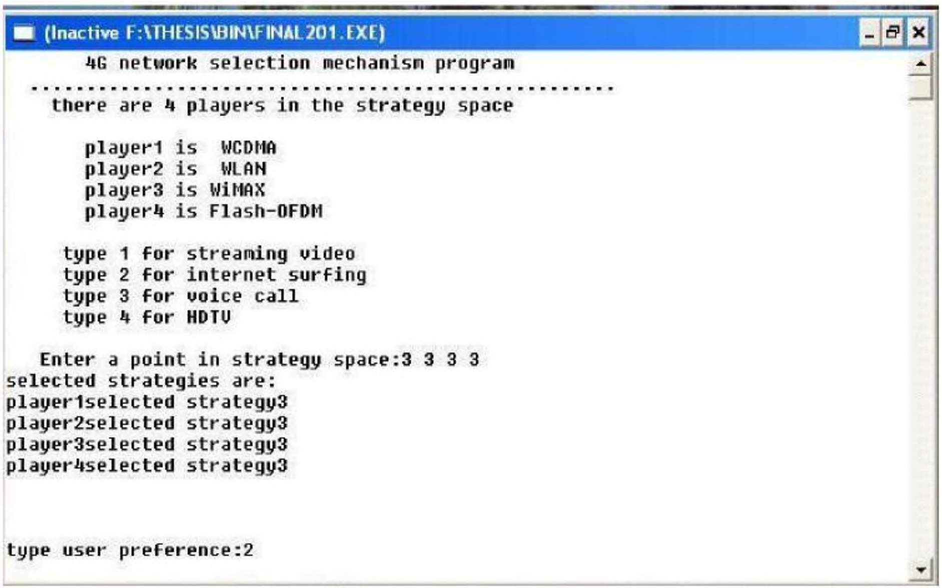


Figure 3. Case I

In the example shown in Figure 3, the strategies (1, 2, 3, 4) selected by the four players are different. So there are no competition and needs no computation of payoffs which is very easy to determine.



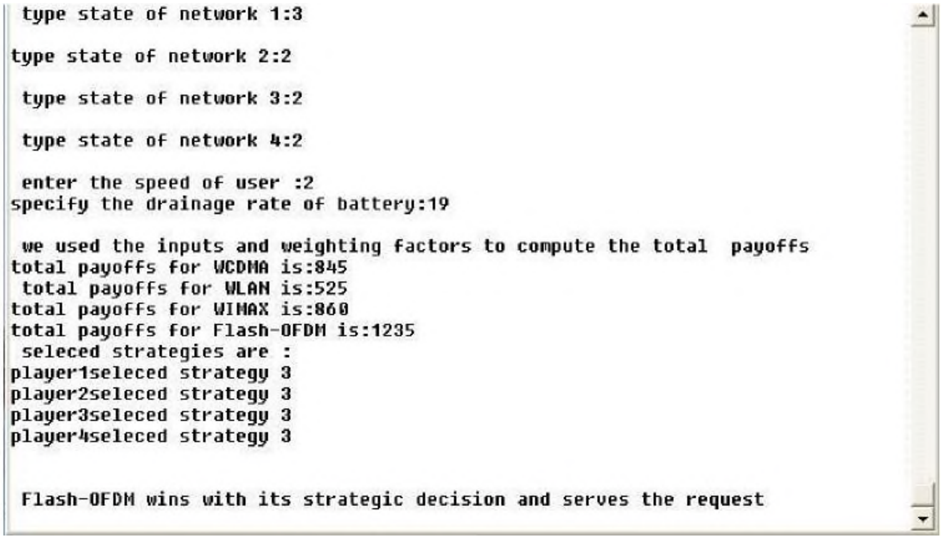
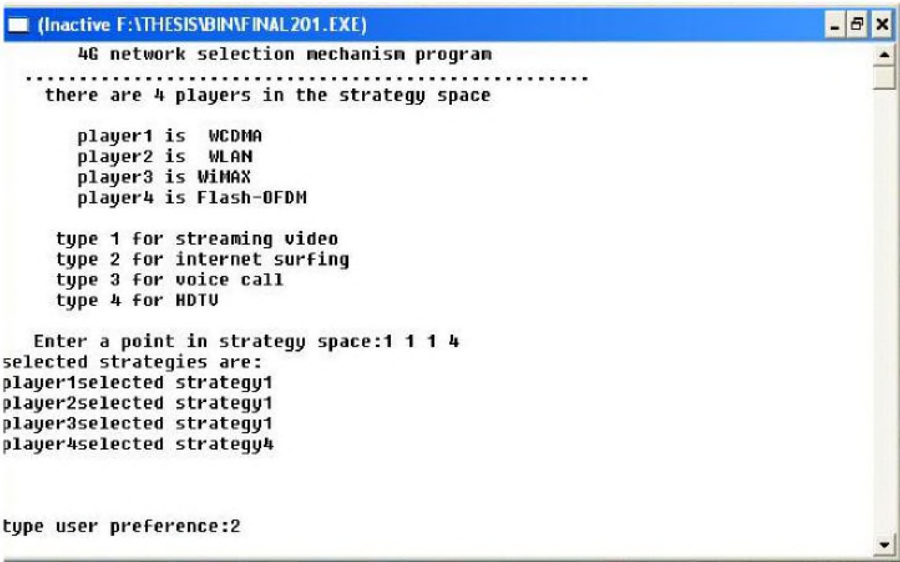


Figure 4. Case II

In this case, the selected strategies (strategy 3) are same for the four players as shown in Figure 4. That kind of competitive condition needs to compute the payoffs. The player containing highest payoffs will win in this competition and serve the request. The other three players will remain idle and wait for the next service request.



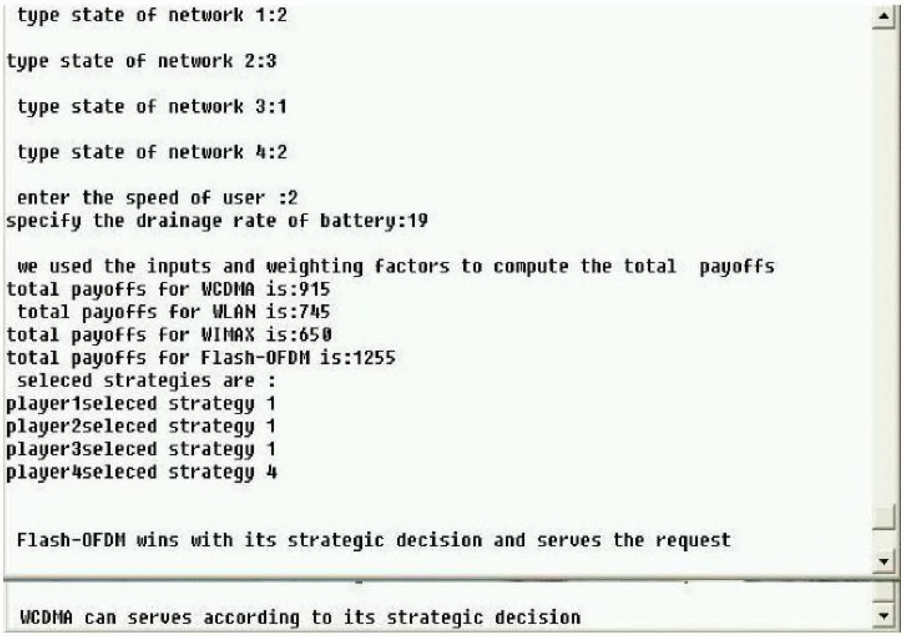


Figure 5. Case III

In that condition, there are two winners. Flash-OFDM has no competitor as it selects the different strategy (strategy 4). So it wins with its strategic decision. WCDMA, WLAN & WiMAX are in a competition as they have selected the same strategy (strategy 1). WCDMA wins in that competition as it has highest payoffs. The other two players (WLAN & WiMAX) will go for the next service requests. The whole process is shown in Figure 5.

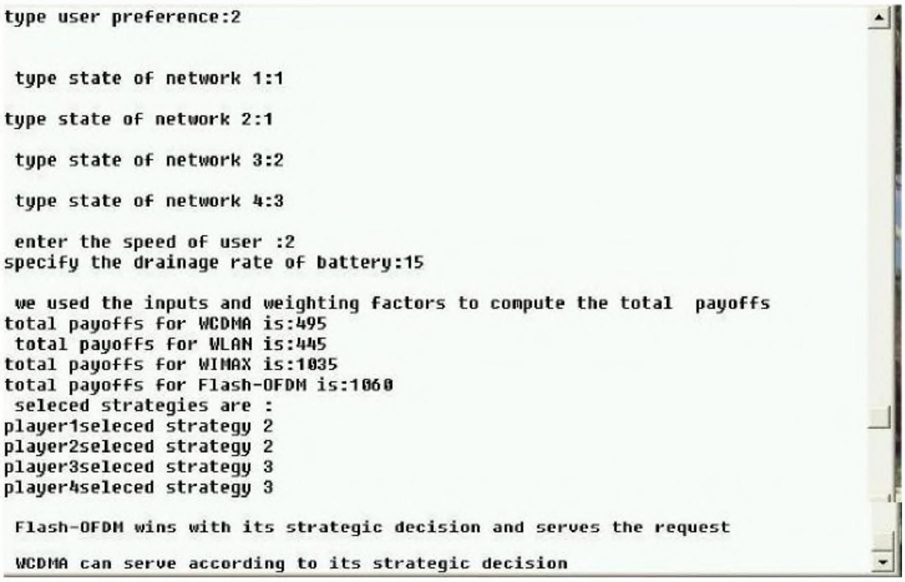
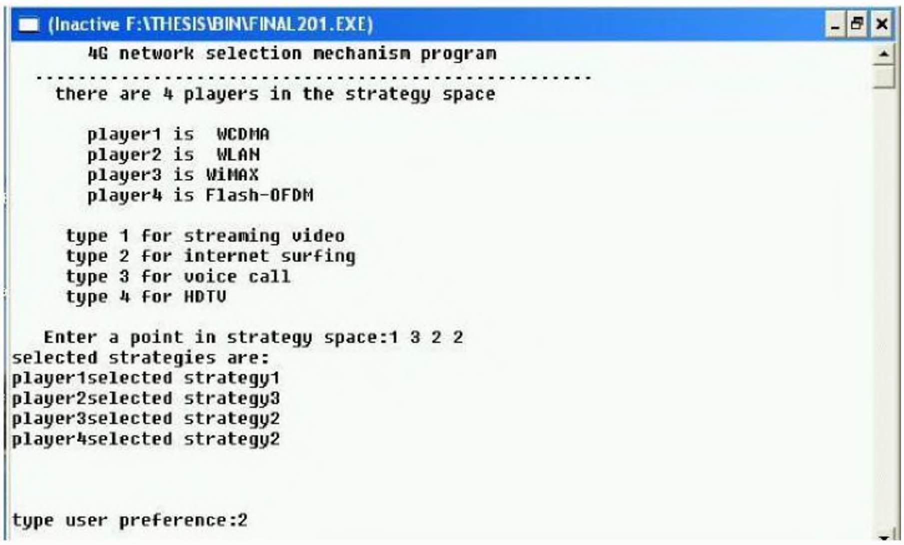
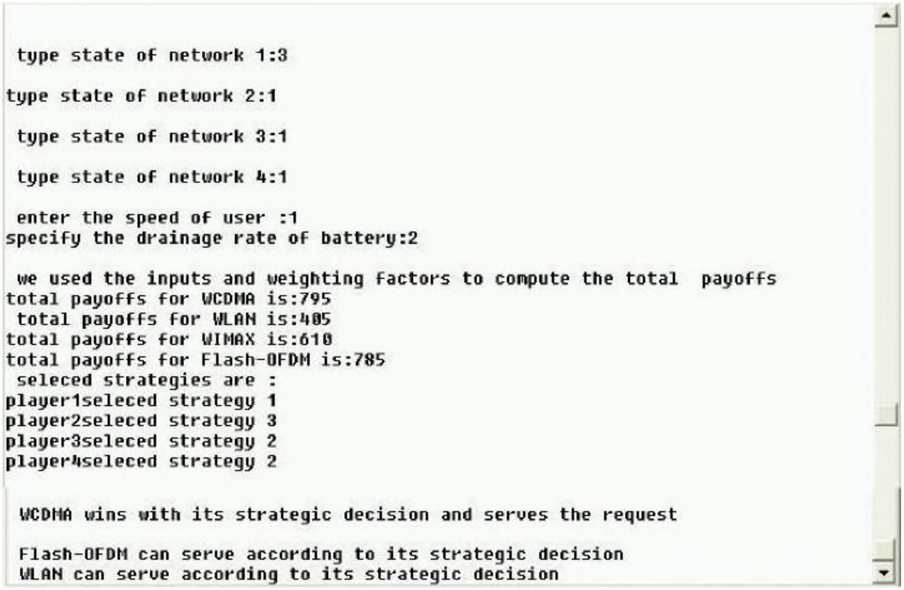


Figure 6. Case IV

In the case depicted in Figure 6, there are two winners. WCDMA & WLAN has a competition for the same service (Strategy 2) to get. WiMAX & Flash-OFDM has also a competition to get the same service (strategy 3). WCDMA & Flash-OFDM are the winners in their respective competition as they have highest payoffs.





```
 type state of network 1:3

type state of network 2:1

 type state of network 3:1

 type state of network 4:1

 enter the speed of user :1
specify the drainage rate of battery:2

 we used the inputs and weighting factors to compute the total  payoffs
total payoffs for WCDMA is:795
 total payoffs for WLAN is:405
total payoffs for WIMAX is:610
total payoffs for Flash-OFDM is:785
 seleced strategies are :
player1seleced strategy 1
player2seleced strategy 3
player3seleced strategy 2
player4seleced strategy 2

 WCDMA wins with its strategic decision and serves the request

 Flash-OFDM can serve according to its strategic decision
 WLAN can serve according to its strategic decision
```

Figure 7. Case V

The example portrayed in Figure 7 is the most interesting as it has three winners in that condition. WCDMA & WLAN are the winners in their respective strategic decisions because they have no competitor. But there is a competition between WiMAX & Flash-OFDM as they have selected the same strategy (strategy 2). Flash-OFDM has the highest payoffs to win this competition.

Thus, the mechanism for selecting the best network at a particular time in a 4G heterogeneous networking system can be easily realized from the above discussed examples.

6. Elongated Problems & Possible Solutions

Five factors including the drainage rate of battery are considered to calculate the payoffs. But Calculation of drainage rate dynamically is problematic when the number of technologies in a heterogeneous networking system is beyond four. Because declaration of quality point for more than 4 players will be difficult.

In case of 5 or 6 players, there will be 5! =120 or 6! =720 combinations. So, dynamic calculation of drainage rate is very difficult and it seems that this dynamic calculation may not be possible conventionally.

However, to overcome the above difficulty, we will calculate the drainage rate statically or directly. The following formula [17] can be used to calculate the drainage rate directly.

T= (AH/A)*0.8 = (WH/W)*0.8 [17] .... (06)

Where,
T = Time in hours.
AH = Amp Hours of Battery.
A = current or Amps used by the load.
WH = watt-hour capacity of the battery.
W = wattage of the load device.
0.8 is the battery Efficiency (assumed).

To calculate AH or WH of a battery at any instant, an ammeter or a watt meter can be added with the battery terminal to get the value of A or W. The time taken by the last load is calculated by a stop watch.

Then,

AH = A*(t-h)

Where,

$$t = \text{initial drainage rate} = \frac{\text{Initial AH (rated on the battery casing)}}{\text{Initial A from ammeter.}}$$

h = time taken by the last load.

Similarly, WH can be calculated.

For Example, a network provider wants to give a service (Voice call) to the users for which the corresponding load consumes 50 watts off a 12 volt deep cycle battery that is rated for 120AH. Now it is important to calculate how long they can provide the service before the battery fully drains.

The Calculation is as below:

WH = 12v x 120AH = 1440WH

W = 50W

T = (WH / W) x .8 = (1440WH / 50W) x .8 = About 23 Hours

Now **Eq^n (01)** is changed to

$\mathbf{P_i=W_AQ_A+W_BQ_B+W_CQ_C+W_DQ_D+W_ET}$ (for direct calculation of Drainage Rate $_{WEQE}$ is replaced by W_ET)

...................................(07)

Then the complexity will reduce & the calculation of the payoffs for any number of technologies can be possible. Other properties of batteries (on which the drainage rate depend) have not been considered in our work.

However, Eq^n (01) is replaced by Eq^n (07) and dynamic calculation of drainage rate is replaced by the above discussed static one. Actually, the value of T in Eq^n (07) is computed separately by using eq^n (06) and all other calculations remain same as before. Then the program will work efficiently with any number of technologies & services.

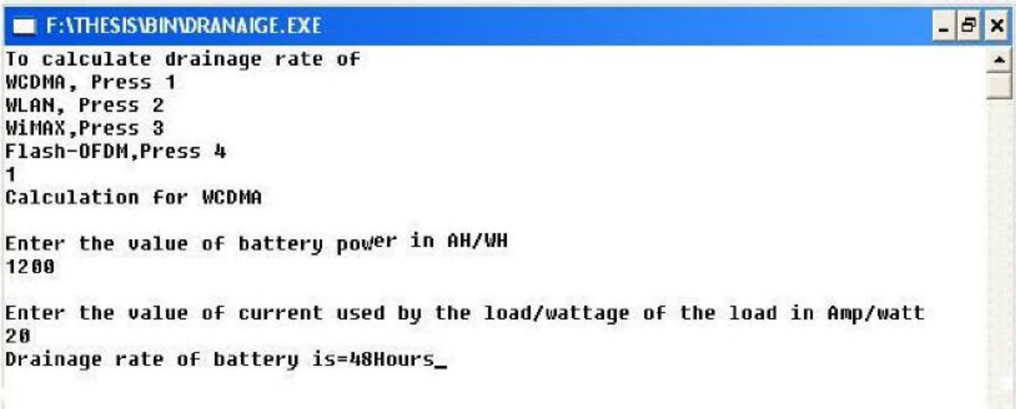


Figure 8. Example output for calculation of drainage rate T

In this example, we have tried to give an idea about how to calculate the drainage rate by a simple program. One can calculate it for all the four technologies by pressing 1, 2, 3, and 4. Then the program will ask for the value of AH or WH and the value of current (A) used by the load or wattage (W) of the load.

Finally the value of drainage rate T will be calculated. In this way the drainage rate is calculated statically. The value of T is put to the Eq^n (07) to calculate payoffs.

7. Conclusion

The objective of this work is to find out the optimum network from a heterogeneous networking system of 4G. To fulfill that goal, the idea of strategy space, weighting factor & quality point is used. Five possible factors reflecting the properties of the networks are taken into account to calculate quality points. By using quality points and weighting factors, a total equation to calculate the payoffs is generated. Finally the payoffs are calculated and compared by C++ programming language to find out the best network. This kind of software will be an essential tool for selecting the best network at any instant.

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