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Comparison Study on Weighting Algorithms for Access Network Selection using MADM Algorithms & Game Theory

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Abstract—*As the fourth generation of wireless network is heterogeneous in nature in which multiple RAT (Random Access Terminals) are available to provide seamless connectivity. In this type of environment, selection of network as per service requirements is an important task. This decision is known as network selection. This selection is done either on the basis of network parameters or on the basis of user`s preferences. This is done by assigning preference weight to each attribute involved in the selection. In this paper, comparative study of selection of network is done using weight calculated on the basis of user`s preferences and network parameters and then selection is done using Game Theory. The analysis results are compared with MADM Algorithm. Simulation results of score obtained in case of WIMAX, WLAN, and UMTS environment is used for the selection of a network. The analysis is done in case of streaming traffic class which requires more bandwidth. The analysis results shows that Game Theory provides better selection as compared to MADM Algorithm on the basis of weights. So, it can be used in fifth generation of wireless network for selection of efficient network.*

1. INTRODUCTION

In the past few years, the vast development in the wireless technology has led to the significant growth in the count of mobile users. In the fourth generation of wireless network, the mobile terminal has the feature of connecting to most suitable access network from the list of available access networks. Therefore, selection of most efficient network for seamless connectivity is the utmost requirement of mobile terminal. This is known as network selection.

Previously, the selection is done by the user`s terminal and it is on the basis of strength of signal received by the mobile terminal. But in the heterogeneous wireless network, this selection scheme is not suitable. Now, the best network is selected on the basis of desired service requirement. The parameters of a network which generally influence the selection of a network are available bandwidth, cost, security, packet loss, packet delay, packet jitter etc.

The different MADM Techniques like SAW, MEW, TOPSIS, VIKOR, GRA etc are available for selection. The weightage given to each attribute involved in the selection can be subjective or objective. In subjective, the weight of each attribute is calculated on the basis of user`s preference while in case of objective, no user`s preference is given and it is calculated on the basis of network parameters. The technique known as AHP and G-1 comes under subjective weighting algorithms while standard deviation method and Entropy method comes under objective weighting algorithms. Game Theory, Fuzzy Logic and many optimization techniques can also be used to select the network from multiple available access networks.

Therefore, in this paper for selection of network, initially an overview of decision making technique i.e. of MADM algorithm and Game Theory is given. The description of Bankruptcy and Evolutionary game theory is presented and then the selection of network using both MADM algorithm and Game Theory (Evolutionary and Bankruptcy) is done. The weight of the attributes is calculated using AHP as subjective weighting algorithm and Standard Deviation method as objective weighting algorithm. The selection results using both MADM and Game theory is presented. At last, the conclusions are drawn from the simulated results obtained.

2. RELATED WORK

An overview of the selection results in this field is given as:

In 4G technology of wireless network, the selection of access network from a heterogeneous environment is an important task. Therefore, for selection initially in [1], introduction about network selection is given. In [2], the selection of network using AHP and GRA is given, where AHP is used to find the weight of each attribute and GRA is used to rank alternatives. In [3] and [4] the selection of network using AHP and TOPSIS is given, where AHP is used to find weight and TOPSIS is used to rank the alternatives but it suffers from ranking abnormality. In [5] brief description about Game Theory is given. It introduces to the basic concept and then a brief description about different types of game models used for the

selection of the network is given. In [6], the selection technique of network using AHP and Game theory is provided. In [7] detail about Evolutionary game model is given. In [8], the selection using Bankruptcy Game Model, which is a N-person Cooperative Game is presented. In [9], detailed explanation about utility function is given, which is one of the parameter involved in the calculation of payoff function involved in the evolutionary game model. In [10], selection using VIKOR is presented. But none of them provide an analysis of selection of network using different weighting algorithms. Thus, in this paper comparative study of selection using weighting algorithms is done in which weight is calculated both on the basis of user`s preference and on the basis of network parameters and these weights are used for selection of network using different decision making techniques.

3. SELECTION OF NETWORK

For selection of a network from a list of available networks, score of each network involved in the selection is calculated. For score, weight associated with each attribute of a network is calculated. After weight calculation, decision making techniques are applied on the network parameters and the score of each network is calculated which is used for selection.

3.1. Weight Calculation

3.1.1. AHP, This is well known technique developed by Saaty and is used for making decision in complex problem. As network selection is a complex problem involving multiple criteria so AHP is used to evaluate the weight of each criterion involved in the selection. Here selection is done on the basis of user`s preference. The explanation of weight calculation using AHP is given in [3].

3.1.2. Standard Deviation Method, This method is based on the fact that the standard deviation of certain index is directly proportional to the variation of the parameter value. Also, if the attribute plays an important role in the selection process then the weight associated with that parameter is large. The criterion of weight calculation based on standard deviation is given in [11].

After weight calculation, the score calculation for selection is given using both MADM algorithm and Game Theory.

3.2. MADM Algorithm

The MADM algorithms used for selection are the following:

3.2.1. TOPSIS, A well known selection technique based on the fact that the chosen network has shortest distance from ideal solution and longest distance from the non-ideal solution. The selection of a network using TOPSIS is given in [4].

3.2.2. VIKOR, A widely used selection technique in which VIKOR index of each available alternative is calculated and the network with a smallest value of VIKOR index is selected as a best alternative. The selection using VIKOR is given in [10].

3.3. Game Theory for Wireless Network

Game theory is a decision making technique used to model complex situation in which the action of decision maker is affected by other agent`s action. These agents may be group, firm or the combination of both these. This concept comes from economics and is used to model competition between companies. But, in case, of wireless network it is used to model competitive situation among nodes and terminal, model situation of resource allocation (in case of limited resources) etc.

The main constituents of game are the Set of players, Set of strategies associated with each player and the utility function associated with the each strategy of each player. The main objective of the game is to maximize the utility function. In a game, when a player cannot benefit anymore by changing its strategy keeping others player's strategy unchanged then this represents Nash Equilibrium.

For selection of network from the list of available networks, game theory can be applied. Therefore, the mapping of game theory elements to wireless network elements is given in Table I.

The game model can be cooperative or non-cooperative, users vs. users, networks vs. networks or networks vs. users. In case of non-cooperative, the selection of strategy (network) is done without any cooperation with any other player in the game while in case of cooperative game, the players cooperate to get maximum gain than the gain obtain without cooperation.

Table 1: Mapping of Game Theory Components to Network Selection and Evolutionary and Bankruptcy Game Model Correspondents.

GAME COMPONENTS	NETWORK SELECTION ENVIRONMENT CORRESPONDENTS	EVOLUTIONARY GAME MODEL CORRESPONDENTS	BANKRUPTCY GAME MODEL CORRESPONDENTS
Players	Agents who are playing game i.e. users or network operators	Users who are competing to access the network.	Available Wireless Networks
Strategies	Action taken by players during game like request for available bandwidth, new call etc.	Selection of an access network	Coalition Formation
Payoffs	Estimated by utility function on the basis of costs, quality, network load etc.	Using Utility Function	Using Characteristics Function

Therefore, in case of cooperative game, a coalition is formed and is given by (N, ϑ) where ϑ is the characteristic function involved in the game and N is the total number of players in the game.

The detailed introduction about game theory is given in [5]. For understanding the selection using Game Theory, take the case of cooperative game (Bankruptcy Game Model) and non-cooperative game (Evolutionary Game Model).

3.3.1. Evolutionary game, As the main constituents of game are set of players, set of strategy associated with each player, payoff of each player for chosen strategy. But in case of evolutionary game, the concept of population is there i.e. the players choosing same strategy forms a group called as population. The number of players forming population can be finite or infinite. Therefore, the game is now played between groups of population rather than between individuals. There could be single or multiple populations. The success of selection of any strategy depends on average payoff of the entire population rather than on the payoff of the individual. The strategy which provides the maximum average payoff is selected .This game find the solution by providing the equilibrium point i.e. at which all players in the population gets maximum payoff.

For selection, payoff function of each individual choosing network from the list of available network is calculated. Let k be the strategy chosen (network selection) from finite set of strategies K. Let n_k be the number of individuals choosing strategy k. The population size is given by$N$, and the population share(number of individual choosing particular strategy) is given by x_k where population size is $N = \sum_{k=1}^{K} n_k$ and population share is $x_k = {}^{n_k}/_{N}$.

$\pi_k(t)$ is the payoff of individual choosing strategy and is given as:

$$\pi_k(t) = U_k\left(\frac{c_k}{n_k}\right) - (p_k * n_k) \quad (1)$$

where, n_k is the number of users choosing network(strategy) k, n_t is the total number of users, p_k is the pricing function of the network k, c_k is the capacity associated with network k, U_k is the utility function of network k and is given as

$$U_k = \prod_{l=1}^{n}[u_l(x_l)]^{w_l}, l = 1, \ldots\ldots n \quad (2)$$

where, l denotes network attributes, u_l is the utility associated with each attribute involved in the selection, x_l denotes any particular attribute and w_l is the weight associated with particular attribute involved in the selection. The detailed explanation regarding utility function is given in [9].

In an evolutionary game, for the selection of network initially random networks are assigned to all the users present in the scenario. Then payoff function associated with each user assigned any particular network in the scenario is calculated, then a combined payoff of all users selecting one particular network is calculated. This combined payoff is used to select the network i.e. the network whose average payoff function is maximum out of all the networks payoff is selected by user at which selection is to be performed in the scenario. This is how selection is done in evolutionary game model. The detailed selection using evolutionary game theory is given in [7].The mapping of game theory components to Evolutionary game mode correspondents is shown in Table I.

Therefore, in this way the new network with payoff information more than the network previously selected is selected as the new network.

This selection technique is particularly used at user side for the selection of network as no cooperation is involved here so each user can select the network from the list of available network without consulting any other user present in the selection environment.

3.3.2. Bankruptcy Game Model, To access/select the resources of a network, Bankruptcy game model is used. In a standard bankruptcy game, a company owes a sum of money to a fixed number of creditors. The sum of claims from creditors is more than the money of the bankrupt company. Therefore, this situation introduces an N-person Cooperative game [8] where coalition formation and evaluation of characteristics function, takes place to satisfy the needs of the creditors. In this, players of the game are seeking for the equilibrium point to divide the money among them. To satisfy every agent, the solution of the bankruptcy game should distribute the money completely and each agent should not obtain money exceeding its demands. As the players enter into coalition there payoff increases. Therefore, Shapley value is used which is a unique way to divide total coalitional payoff among the players of the game. We can also use other function to divide the coalitional payoff.

In terms of selection as it is a cooperative game where network tries to cooperate with each other to provide resources to the new connection. Coalitional formation tells us how many potential resources (PR) a network is potential to provide to mobile user. After coalition of the networks the payoff of each coalition is calculated using characteristics function and also the total obtained payoff of coalition of network is divided among the players of the game (networks) using Shapley value. The detailed selection of network using Bankruptcy game model is given in [6].

The mapping of game model to network selection in case of bankruptcy is given in Table I.

This technique is usually used at the network operator side to provide resources to user if user has new resources requirements. Here cooperation among the network is there and therefore if one network is unable to provide resources to the user then coalition provide the required resources to the user. The computational complexity is small and also it provide a fair solution of distribution as compared to other methods proposed in the literature to compute the solution the solution of N-person cooperative game.

4. SYSTEM MODEL & NETWORK RANKING

The simulation scenario is composed of two UMTS, two WLAN and two WIMAX as available networks. The available network along with their attributes is given in Table II. For selection of network, score of each network involved in the simulation is calculated. The simulation is carried in MATLAB.

For weight calculation, AHP (Subjective weight calculation) and Standard deviation method (Objective weight calculation) is used and for score calculation, MADM`s TOPSIS, VIKOR and Game Theory`s Bankruptcy Game Model and Evolutionary Game Model is used. The selection in case of evolutionary game is done by taking 30 users and 10 iterative simulations. The score calculation and network ranking is done in case of streaming traffic class. As streaming requires high bandwidth so bandwidth is considered as the most important attribute as per user`s preference followed by cost per byte and other parameters.

The different attributes of the network are the following, AB(Available Bandwidth),PD(Packet Delay),PJ(Packet Jitter),CB(Cost per Byte),PL(Packet Loss).

The weight of each attribute involved in the selection using AHP and Standard deviation method is shown in Table III. The consistency ratio in case of AHP Method is 0.076 i.e. <0.1.Therefore, these weights are acceptable.

In case of TOPSIS, Evolutionary Game Model (Game Model 1) and Bankruptcy Game Model (Game Model 2), the network with a highest score is selected as the best network while in case of VIKOR, the minimum score network is selected as the best network.

Table 2: Different Network Parameters

	AB (Mbps)	PD (ms)	PJ (ms)	CB (%)	PL (per 10^6)
UMTS1	0.1-2	25-50	5-10	60	20-80
UMTS2	0.1-2	25-50	5-10	80	20-80
WLAN1	1-11	100-150	10-20	10	20-80
WLAN2	1-11	100-150	10-20	5	20-80
WIMAX1	1-60	60-100	3-10	50	20-80
WIMAX2	1-60	60-100	3-10	40	20-80

Table 3: Network Attributes Weights

	AB	PD	PJ	CB	PL
AHP	0.5028	0.1344	0.0376	0.2602	0.0650
Standard Deviation	0.3791	0.1882	0.1449	0.2878	0.0000

Whereas, in case of standard deviation method for weighting algorithm, the weight of attributes are calculated from network parameters. So, the selection of any network depends on parameters. As observed from Table III the important attributes are Available Bandwidth and Cost per byte as compared to other parameters. So, observed from Table V, in some cases WIMAX2 and WIMAX1 providing maximum bandwidth are selected as best network while in some cases WLAN2 providing minimum costs is selected. In terms of complexity of procedure used for selection of network, the calculation in case of TOPSIS and VIKOR is simple, while in case of Game Theory Models used for calculation of score, the procedure is much more complex. In case of Bankruptcy Game Model used for selection which is a cooperative game model, here selection depends on the coalition formation, therefore as the number of networks involved in the selection increases more number of coalition formation takes place. This is not possible in case of MADM algorithms.

Also, in case of Evolutionary Game model as initial selection of network is random in nature then the payoff function associated with each network is calculated and then average payoff function of all users selecting same network is calculated and this is used for selection of network.

Due to random selection, iteratively selection is to done to get more accurate results. Due to random nature of selection every time when selection is done then new network is selected having favorable attributes. This is not possible in case of TOPSIS and VIKOR as in this case a fixed network is selected.

Table 4: Network Score using AHP Algorithm

	TOPSIS	VIKOR	GAME MODEL 1	GAME MODEL 2
UMTS1	0.2672	0.9396	-0.2691	0.0540
UMTS2	0.3138	1.0000	-0.3809	0.0527
WLAN1	0.1557	0.7681	0.8960	0.2126
WLAN2	0.1531	0.7530	2.6501	0.2037
WIMAX1	0.7768	0.0757	7.3926	0.2341
WIMAX2	**0.8120**	**0.0000**	**9.9130**	**0.2429**

Table 5: Network Score using Standard Deviation Algorithm

	TOPSIS	VIKOR	GAME MODEL 1	GAME MODEL 2
UMTS1	0.2500	0.8949	-0.2700	0.0803
UMTS2	0.2123	1.0000	-0.2979	0.0766
WLAN1	0.4061	0.8346	0.9939	0.1377
WLAN2	0.4349	0.7943	2.0421	**0.2473**
WIMAX1	0.6417	0.1959	**13.1671**	0.2236
WIMAX2	**0.7613**	**0.0000**	3.6710	0.2345

5. CONCLUSIONS

In this paper, we provide the simulation study of selection of network from the list of available networks consisting of two UMTS, two WLAN and two WIMAX network. The selection is done by considering the impact of weight algorithms, if user`s preference is given (AHP Method) and if user`s preference is not given (Standard Deviation Method).The important parameter in case of AHP algorithm is available bandwidth while in case of Standard Deviation method both

available bandwidth and cost is considered as important parameters. The analysis is done in case of streaming traffic class which requires high bandwidth. The results of simulation shows that WIMAX2 is selected as best network using AHP`s weight while using the weight calculated via standard deviation method shows that in some cases WIMAX2 and WIMAX1 or in some cases WLAN2 can be selected as best network. Out of these WIMAX2 and WIMAX1 provide more available bandwidth while WLAN2 is available at low costs as compared to all networks available in the list. The analysis using MADM algorithm takes only highest weighted parameter into its consideration while in case of Game Theory Model more than one weighted parameters are taken into consideration for the selection of network. Therefore, Game Theory provides more accurate selection results as compared to MADM algorithm for the selection of network from the list of available network.

In future, we will see the impact of group weighting on the selection of network in which both weighting algorithms(one taking into consideration user`s preferences and another without user`s preferences) are combined to provide the cumulative weight and then selection of network is done using MADM Algorithm and Game Theory as decision making technique. We will also include more Game Theory Model in the selection of network.

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