Abstract

Objectives: Heterogeneous environment is formed by co-existing interworking networks, with the objective of providing mobile users with best connectivity at anytime. This is facilitated by handover process. In this paper we have proposed Utility Theory based vertical handover decision algorithm, taking into consideration utility functions/parameters like bandwidth, monetary cost, security and power consumption levels of candidate network available for handover. Methods/Analysis: The proposed algorithm uses hybrid of Fuzzy logics and AHP to assign weights to the parameters and since the algorithm is utility based, the network are ranked using simple weighted sum of the parameters. Findings: The proposed algorithm selects the network which satisfies all the network selection criteria. Higher the level of user satisfaction served by the network, more it is suitable for handover in heterogeneous environment. Conclusion/Applications: The proposed algorithm provides higher level of user satisfaction. It is well suited for random and imprecise wireless environment since it makes use of fuzzy logics instead of crisp values. Furthermore to check its applicability in real time the proposed algorithm can be implemented on a simulation tool.

Keywords: FAHP, Heterogeneous Network, Network Selection Algorithm, Utility Theory, User Satisfaction

1. Introduction

With the introduction of wireless technologies and enhancement in these technologies the mobile users’ demands to access these services has increases. Users’ aims to stay connected to best network so as to get best QoS. To facilitate mobile user with these varying services provided by different network technologies, these technologies are integrated to make them co-exist and interwork in a wireless environment known as heterogeneous Environment (HETNETs). 4G networks also known as Heterogeneous Network (HETNET), framework is based on the concept of integration of various targets which include terminal, users, applications and networks. The motive of 4G is to replace former technologies with single IP based core network standard for packet data, video, voice and control.

The objective is to provide mobile users with the facility of seamless roaming throughout the network.

1.1 Features of HETNETs

- HETNETs provide users with higher data rate at low transmission cost. The data rate of 4G is 10 times greater than that of 3G technology, with bit rate upto 100 Mbps and bandwidth.
- Higher network capacity and next generation multimedia support due to multiple networks, network capacity of 4G is nearly 10 times than that of 3G networks.
- HETNET is able to provide service to the users anywhere anytime: This is possible due to the integration of various networks.
HETNET provides users with connection to the best network depending on their needs\textsuperscript{3,4}.

1.2 Challenges in HETNETs

Challenges in heterogeneous networks are categorized into network related, services related and mobile terminal related challenges\textsuperscript{5,6}.

1.2.1 Network Related Challenges

In heterogeneous technology, different RATs co-exist and interwork to provide mobile users with various services. Some of network related challenges are integrated network framework i.e. integration of multiple networks to interoperate in HETNETs, support for seamless mobility, Quality of service for the users and Security.

1.2.2 Terminal Related Challenges

To access different network technologies and services provided by the networks on same user terminal, intelligent and multimode mobile terminal are necessary. Multimode user terminal can be achieved by using adaptive software radio approach. Another important factor to be considered is the requirement of multiple antennas.

1.2.3 Service Related Challenges

The network operators in HETNETs need to maintain multiple services to provide improved QoS to the mobile users. With the increase in diversity more absolute system for accounting and billing is required, so that customers can access different services provided by number of service providers simultaneously instead of being connected to a single operator. The multimedia services offered by different operators have different charging policies. So to decide an optimum tariff for all services is very critical in 4G networks.

1.3 Mobility Management in HETNETs

Mobility in HETNETs is divided into two broad areas and depicted in Figure 1. The two main features of mobility management are handover management and location management. The optimal choice of network and to stay connected to best network is main motive of heterogeneous technology. Mobility management motive is to make mobile terminal capable of choosing best radio access technology anytime anywhere. Location management is required to identify the current network to which the mobile terminal is connected\textsuperscript{4}.

Handover is process of maintaining users’ active session and facilitating the user to roam around the networks as users changes his PoA. The user terminal makes the choice of radio access technology among all the candidate networks available in the heterogeneous environment for execution of handover process. Network chosen for handover and the exact time to execute the handover process depends on the handover algorithm designed for the handover process\textsuperscript{6}. Framework of multimedia services provided in 4G technology should be adaptable to various changes in the network as changing radio access technology during handover brings drastic changes in the network.

2. Handover

Handover is process by which mobile user is switched between different RATs so that mobile user can gain access to different services provided by other radio technologies. The services provided by these technologies vary from each other in terms of coverage area, RSS, monetary cost, throughput, security etc. a mobile user may want access to different services at different times.

2.1 Classification of Handover

Handover can be differentiated into five categories as shown in figure and are discussed below\textsuperscript{7,8}.
2.1.1 Depending on Mobility

- Horizontal or Intercell handover takes place in homogeneous environment.
- Vertical handover: When mobile user switches between network technologies of different type. It is also known as intra-cell handover.

2.1.2 Depending on Direction

- Upward handover, when mobile terminal switches from network with coverage area larger than that of the current network.
- Downward handover, when mobile terminal is switched to network with smaller coverage area than the current network.

2.1.3 Depending on Process

- Hard handover or Break Before Make handover. It occurs when the mobile terminal disconnects from the current network before making connections with the target network.
- Soft handover or Make Before Break handover. It occurs when mobile terminal maintains its connections with base station of current network while creating the connections with target network.

2.1.4 Depending in Decision

- Imperative handover: When a mobile node switches its PoA due to some technical issues like weak signal strength or less coverage area.
- Alternative handover: It is used to provide user better performance regardless of any absence or presence of technical issues. It considers number of network selection parameters like velocity, monetary cost, available bandwidth, QoS and user preferences.

2.1.5 Depending on Control

- Network controlled handover: In NCHO, network has primary control over the handover process. The network operator aims to manage the network related resources and to fulfil the user’s requirements when he is connected to their network, so as to maximize their revenue.

- Mobile controlled handover: In MCHO, the mobile terminal has main control over the handover process. The mobile user aims to get best connection i.e., wants to get connected to best possible network among the available networks in heterogeneous environment, in order to satisfy their requirements and preferences without considering the network related complexities.

2.2 Handover Process

Handover process in divided into four phases as shown in Figure 3.10.

![Figure 2. Classification of handover.](image1)

![Figure 3. Handover process.](image2)
2.3 Network Selection Parameters

Network selection parameters are divided into 4 categories as shown in Figure 4.2.

2.4 Network Selection Techniques

Three issues that dominate network selection are: 11-15

- Selection of most appropriate handover parameters.
- Identification of algorithm that fully exploits these parameters.
- Identification of weighting technique that weights each criterion.

2.4.1 Multiple Attribute Decision Making (MADM) based

MADM includes many network selection methods as discussed below:

- TOPSIS is applied to determine the ranking of access networks. The network selected has ranking closest to the ideal solution and is obtained by considering the best value for each VHO parameter.
- AHP method is used to determine the weight of each criterion by dividing network selection problem and assigning weights to each subproblem.
- GRA is used to rank the candidate network and select the network with the highest ranking.
- SAW method is used to calculate the overall score of candidate network by addition weighted sum of all the selection parameters.

2.4.2 Fuzzy logic based network selection solution

In this network selection technique, physical measurements are converted into fuzzy logics. In this technique user and network side attributes are placed in the fuzzy logic controller to carry out final decision process, yielding the result called fitness ranking. Fuzzy Logic deals with imprecise data and multiple inputs for VHO decision which increases the efficiency of handover and reduces unnecessary handover.

2.4.3 Game theory based network selection

Game theory is set of mathematical models designed to examine the decision process, estimate the outcome and select favourable approach. Game theory is classified into non-cooperative and cooperative game theory. Cooperative game theory studies the behaviour of collaboratively working rational players while non-cooperative game theory studies the interaction results of competing players where players independently choose their strategy to maintain their service and minimize cost. The players in game theory are user and the network.

2.4.4 Utility theory based network selection

Utility is the measure of user satisfaction. In a heterogeneous network, every candidate network available for handover has a utility function. The network providing greatest utility value is chosen for handover, which is obtained from the weighted sum of selection parameters. The network which provides maximum utility value and satisfies user demand is best for handover. Selection of utility function is challenging since the function is related to user preferences or user priorities for low cost, improved QoS and increased bandwidth. Utility theory based network selection algorithms can take many forms due to different user preferences for the network.

3. Proposed Methodology

Flow chart of the proposed technique is explained in Figure 5. Parameters considered necessary for selection of best alternative are bandwidth (should be large), monetary cost (should be less), security (should be high) and power consumption (should be less).

3.1 Utility Theory based Approach

Step 1: Construction of problem structure hierarchy model using AHP.

Step 2: Generating comparison matrix for the parameters. This matrix plays a significant role in selection of best alternative for handover execution. Comparison matrix makes decision makers aware of importance of one element/parameter over the other.
Step 3: Generation of TFN for expressing the importance of parameter over the other.

Step 4: Calculation of weights of the parameters using FAHP.

Step 5: Ranking of alternatives based on the level of satisfaction served by each of the network selection parameter.

User satisfaction provided by each network is calculated by equation 1

\[
Usersatisfaction = \frac{prefbw - actualbw}{actualbw}(w_{bw}) + \frac{prefcost - actualcost}{actualcost}(w_{c}) + \frac{prefsec - actualsec}{actualsec}(w_{sec})
\]  

Where pref bw is preferable bandwidth = 500 kbps, pref cost is preferable cost = 5 rupee/min, pref sec is preferable security = 3, is weight of bandwidth, is weight of cost and weight of security parameter generated by FAHP technique.

Three networks are taken into consideration for handover process are the values of network selection parameters are given in Table 1.

4. Experimental Results

The graphs below are obtained from the simulation of proposed algorithm on MATLAB tool. These graphs explain the level of user satisfaction provided by each network selection parameter. Figure 6 shows satisfaction

Figure 5. Flow chart of proposed methodology.

Figure 6. Level of user satisfaction served by cost of each network.

Figure 7. Level of user satisfaction served by bandwidth.
Table 1. Network and their selection parameters

| Network  | Bandwidth | Monetary cost | Security | Power consumption |
|----------|-----------|---------------|----------|------------------|
| Network 1 | 2         | 3             | 3        | 1                |
| Network 2 | 1         | 2             | 2        | 2                |
| Network 3 | 0.384     | 5             | 7        | 1                |

Figure 8. User satisfaction v/s network.

level served by monetary cost of each network, network 2 is highly preferable for handover and network 3 is least preferable in terms of cost. Figure 7 shows network 1 is highly preferable and network 3 in least preferable in terms of bandwidth and in term of security network 3 is highly preferable and network 1 is least preferable. Figure 8 shows network 3 is highly preferable and network 1 in least preferable in terms of security. From the satisfaction level of all the network selection parameters we conclude that network 2 satisfies all the selection criteria and hence is chosen for handover, same is depicted by Figure 9, which shows that network 2 is highly preferable and network 3 is least preferable. These results are generated by the preferable values for network selection.

5. Conclusion

In heterogeneous environment, mobile user wants to stay connected to best network. To facilitate this, handover process is required. We have proposed Utiliuty theory i.e., user satisfaction levels based VHO algorithm for HETNETS. Since wireless environment is purely random and imprecise, we have combined Fuzzy logics with AHP for weight generation. The proposed algorithm is purely based on the level of satisfaction level served by each parameter. Higher the satisfaction level of the network, more it is preferred for handover. The proposed algorithm provides users’ with a network that best satisfies all the network selection criteria. This algorithm can be further used for real time simulations, which will provide enhanced results and better satisfaction to the users.

6. References

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