Mobile Terminal Energy Aware Vertical Handover Decision Processes in Heterogeneous Wireless Mobile Networks

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ABSTRACT

Heterogeneous is networks is integral in fourth generation to make the best possible use of the combined resources of available. To have seamless communication and mobility between these heterogeneous wireless access networks, support of vertical handover (VHO) is required. Vertical handover decision algorithms are essential components of the architecture of the forthcoming Fourth Generation (4G) heterogeneous wireless networks.

With regard to vertical handoff, the target network selection is a bigger challenge. Thus, it is desirable to devise algorithms which select the most efficient network among all options as the handover target, so that users can benefit from the access in an "always best connected" manner. In this paper, we propose vertical handover decision algorithms for LTE, WiMAX and Wi-Fi heterogeneous wireless networks which maximize user satisfaction level and minimize the probability of handover connection failure. Quality factor function is used to represent multiple numbers of vertical handover criteria which will select the best available network based on a set of weighted parameter values.

According to the results gathered from the Matlab simulation environment, the proposed algorithms maximized user satisfaction level in terms of data rate, latency and energy consumption of mobile terminal and minimized the probability of vertical handover connection failure.

I. INTRODUCTION

The modern mobile communication has evolved from First Generation (1G) analog communication to limited data capable 2G to existing 3G data centric communication [5]. Along with higher data rates the 4G focus is seamless, high speed mobility with ubiquity and quality of service (QoS). Mobile user's demand of ubiquity and QoS for multimedia applications cannot be fulfilled by a single access technology. This is because each of the technologies varies for greater market share, thus having an edge over the other in one aspect or the other [6]. For instance, Wireless Fidelity (Wi-Fi) has limited coverage range but has edge with high data rate access for short area and low access cost; Worldwide Interoperability for Microwave Access (WIMAX) can be an optimal solution provides intermediate coverage in a radius in miles with but relatively a bit costly and it needs also point to point communication. Long Term Evolution (LTE) provides wide area coverage with high data rate but high cost to both network operators and end users. The diverse wireless access technologies thus can complement each other in the heterogeneous network environment to provide coverage, high data rate access and economy. This necessitates the seamless integration of wireless access technologies [7].

Vertical handover (VHO) can integrate diverse wireless access technologies by allowing the transfer of control of a communication session from one access technology to another. This would not only provide the mobile user the Always Best Connectivity (ABC), but also helps improve global network utilization by load balancing and also facilitating network congestion control. This creates a win-win situation for both the end user and the service provider [4].

Transfer of a live call onto a new channel within the same access technology is a reality today. Not only GSM/UMTS/LTE/LTE-A advance but WI-FI (IEEE 802.11r) and WIMAX (IEEE 802.16e) also support horizontal handover. Enabling the mobile devices to change the access technology seamlessly, such that the procedure is transparent to the application and session is maintain uninterrupted with an acceptable level of QoS, is the next challenge [12].

The need for VHO has also added a new dimension to the traditional handover decision metric. Different kinds of wireless networks, for example, have incompatible signal strength metrics; in this case the handover decision metric may include received signal strength (RSS), data rate, latency, battery power, user preference, network conditions, cost, security etc. The core network can initiate the handover for the sake of load balancing as well. A mobile user may handover the live session to the new access network in order to reduce the cost of the call when a better option becomes available [4].

The all-IP will play a pivotal role in the convergence of diverse access technologies. All technologies are converging towards IP due to its flat rate access cost and low cost of entry.

The core network, for example, for LTE, WI-FI and WiMAX is IP. LTE is also a packet-based all-IP network. Thus, with this All-IP future, the diverse access technologies can be integrated. [9].

II. LITERATURE REVIEW

In this section, we present a review of various handoff decision strategies.

- The work in [1] has analyzed vertical handoff decision strategy which considers the performance of the overall system. This strategy uses parameters like network bandwidth, RSS and variation of RSS. The performance of this strategy has been analyzed and it is observed that it greatly reduces the handoff call dropping probability than the current existing strategy.
- The work in [2] has proposed cost function based strategy with RSS, network bandwidth, monetary cost and user preference as the vertical handoff decision parameter. Network selection function with lower values is selected as target network. This evaluation carried out by considering network resources and decreases the probability of call blocking and call dropping.
- The work in [3] has explained the decision strategy for achieving the service continuity with minimum processing delay. Further, it is classified and compared in two schemes Centralized Vertical Handoff Decision (C-

VHD) and Distributed Vertical Handoff Decision (D-VHD).

- In [4] authors objective is to provide seamless high data rate and multimedia services across different wireless networks. To achieve this they have proposed Simple Additive Weighting (SAW) based vertical handoff mechanism and reduce the processing delay used while calculating the network selection function.

However, previous works which have been reviewed in are content only with selecting one target RAT. Our work search for resources by priority of RAT which helps to select more than one in case of resource constraint of target RAT. Also we give exhaustive consideration of the energy of the mobile terminal and the type of service as real-time and non-real time service as they have different characteristic.

III. STATEMENT OF THE PROBLEM

In the literature, a variety of VHO approaches have been proposed to provide seamless handover. These VHO approaches lack an exhaustive consideration of the energy of the mobile node and the type of service as real-time and non-real time service have different requirements. Some of other VHO approaches are considering one parameter, mostly received signal strength, to make handover decision but considering only one parameter is not enough to select the best available network. Also, previous works which have been reviewed in are content only with selecting one target RAT for the checking resources which cause handover connection failure when the selected target network have resources constraint to handle VHO.

IV. OBJECTIVES OF THE RESEARCH

The main objective of this work is to propose a vertical handover decision mechanism for heterogeneous wireless networks which maximize user satisfaction level and minimize the probability of handover connection failure. The aim is divided into following sub-categories:

- Propose an algorithm for vertical handover to select the best available network.
- Maximize user satisfaction level from data rate, latency and energy consumption of mobile terminal point of view.
- Minimize the probability of vertical handover connection failure.

V. PROPOSED SYSTEM MODEL

In a heterogeneous network environment, where multiple options of connectivity are available, the target network selection is a bigger challenge. Thus, it is desirable to propose algorithms which select the most efficient network among all options as the handover target, so that users can benefit from the access in an “always best connected” manner.

a. Problem Formulation

Consider an urban area where a LTE, WiMAX and WI-FI networks coexist, as shown in Figure 4.1 the big red point represents LTE base station, blue point represents Wi-Fi access point, yellow point represents WiMAX base station and the small red point represents the mobile terminal. We use the tightly coupled architecture in which a single (RNC) maintains the network information. This can be achieved by requesting each base station to periodically update the resource usage and the quality of currently served applications. All handovers occurred in this area are managed and optimized at the RNC.

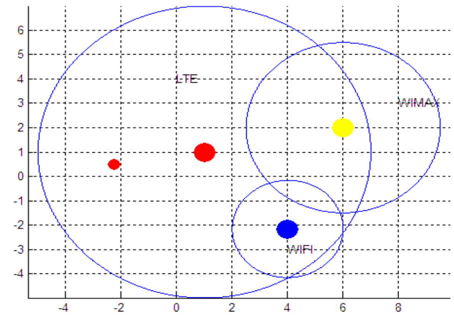

Figure 4.1: Coexisted Networks of LTE, WiMAX and WI-FI

b. Parameters

i. Received signal Strength
ii. Data Rate
iii. Latency
iv. Energy Consumption

c. Optimal RAT Selection

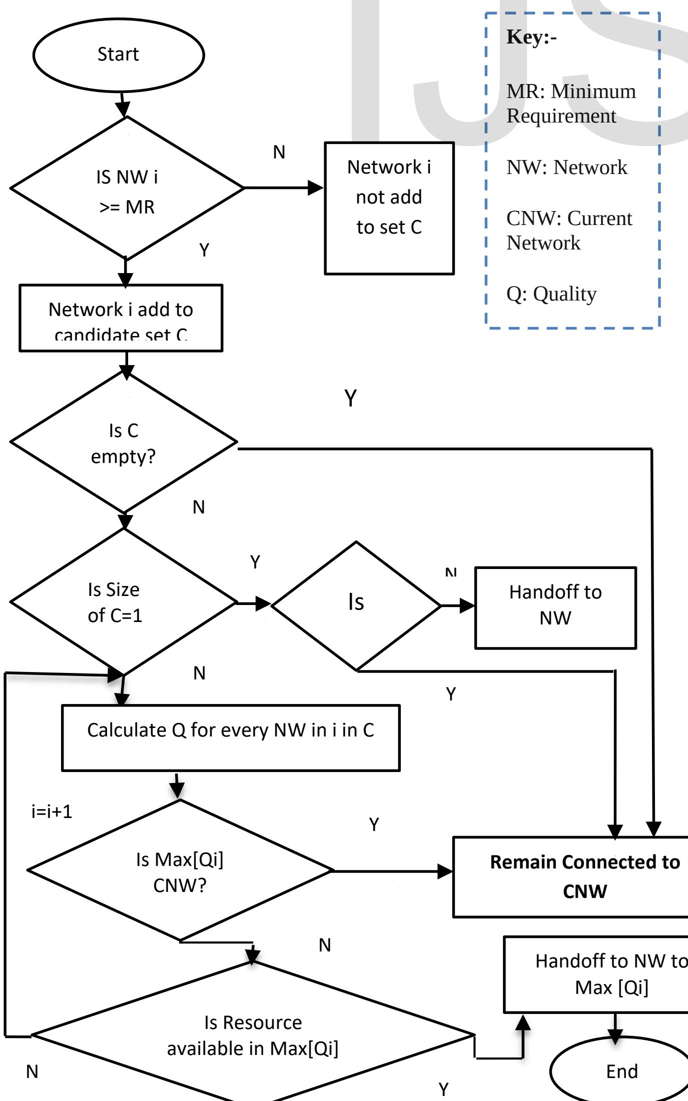

Figure 4.2: Proposed Handover Decision Algorithm

The proposed algorithm in figure 4.2 select the best network as the handover target among available options based on four parameters, received signal Strength, data rate, latency, and energy consumption which have an effect on whether or not hand of should tack place or not. Here we considered 3 integrated different networks. Identity is given to each network as Network1 is LTE, Network2 is WiMAX and Network3 is Wi-Fi.

In the first stage algorithm evaluate that the minimum requirements of parameters of each network is supported or not. That is all the four parameters need to be above the thresholds. If the minimum requirements for a particular network satisfied, this network will be added to the candidate network set *C* .Note that the set *C is* set to be empty at the beginning of every handoff decision.

According to the size of the candidate network set *C*, the propose decision algorithm generally falls into three cases. One is that the set *C* is empty, MT remains connected to the current network. Another is that there is only one member in set *C*. If the only network is the current network, MT stays in the current network no need of vertical hand over; otherwise, MT decides to perform vertical handoff procedure to be associated with the network. The other is that more than one network have been added into the set *C*.

There is more than one network in candidate C we will calculate the quality factor Qi in equation 4.5 for each network with the reference of weights assignment algorithm in figure 4.3. Then Sort and select the network with the maximum value of Quality factor. If the network with the maximum value of Quality factor is the current network, MT stays in the current network no need of vertical hand over because the current network is the best network. If the network with the maximum value of Quality factor is not the current network the algorithm cheek the availability of resources in the target network, if resources is available in the target network it will vertical handoff to the target network take place otherwise, algorithm will cheek the network with the second maximum Quality factor value and continuous in the priority list.

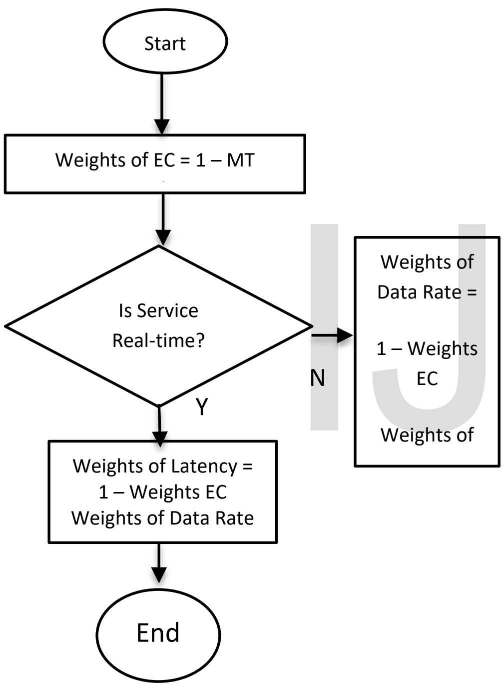

Figure 4.3: Weights Assignment Algorithm

The weights assignment algorithm realizes the type of service and the power level of the MT, and generates weights for data rate, latency, and energy consumption parameters. The algorithm calculates weight for the parameters using a method described below.

Initially, the following assumptions are made:

- The battery power level of the MT is pw, where 0 < pw <1, (pw = 0 means the battery power runs out and pw = 1 means the battery has the maximum power).
- The weight factors of the four network parameters, Data Rate, Latency, and Energy Consumption, are W_{dr}, W_l, W_{pc} respectively, where $W_{pc} = 1 - pw$ and $W_{dr} + W_l + W_{pc} = 1$

If the service is real-time, the Latency of the network will be extremely important in consideration with the battery power level of the MT. the weight of Latency will be $W_l = 1 - W_{pc},\ and\ W_{dr} = 0$, otherwise, non-real-time the emphasis will be in data rate and the weight of data rate will be $W_{dr} = 1 - W_{pc},\ and\ W_l = 0$.

VI. SIMULATION, RESULT AND DISCUSSION

A. Simulation

In the simulation it is assumed that three candidate networks are available, including LTE, WI-FI and a WIMAX. Their parameters are listed in Table 5.1

TABLE 5.1 PARAMETER USED TO COMPARE RATS

No	Parameters	Values
1	Received Signal Strength	Calculated using equation 4.1
2	Data Rate	Calculated using equation 4.2
3	Latency	Calculated using equation 4.3
4	Energy Consumption	Calculated using equation 4.4
5	Weight	Assigned using Algorithm in Figure 4.3
6	Service Type	Random Real-time/non Real-time
7	User movement	Random

To implement and the proposed model we used Matlab2009. We developed and simulated LTE, WiMAX and WI-FI networks in matlab. We assume that the mobile user is currently connected to LTE and moving in random direction using the real time or non-real time application. In the simulation, we deploy one LTE, one WIMAX and one WI-FI network in which LTE Covers the majority analysis area, WIMAX and WI-FI partly overlay the service Area. LTE covers the majority analysis area around 4 km diameters and WIMAX around 3.5 km diameter and a set of 20 WI-FI networks each separated by maximum of 100m and cover a total 2 km. In the simulation we considered mobile terminal is moving randomly using a real time or non-real time service.

Simulation Result on Different Scenario

Consider the situation in which there are three different RATs (LTE, WI-FI and WIMAX). The LTE covers most analysis area as well as WI-FI and WIMAX partly overlay the service area. While the MU is currently connected to LTE and Using VoIP service, it has started moving toward the WI-FI and WIMAX hotspot area.

For this simulation the following assumptions made

- When the mobile terminal change its color to read, the current quality of LTE is Better than the other RATs at the current Situation
- When the mobile terminal change its color to Blue, the current quality of WI-FI is Better than the other RATs at the current Situation
- When the mobile terminal change its color to Yellow , the current quality of WIMAX is Better than the other RATs at the current Situation
- Status of the battery power of the Mobile Terminal is extreme importance over all other parameters
- For real time service like VoIP the Latency time is very importance over all other attributes except the Battery Power.
- For non-real time service the data rate is very importance over all other attributes except the Battery Power.
- Received Signal Strength must be above the minimum requirement the service needs

Scenario 1:

The mobile terminal is in the area of only LTE network coverage is available

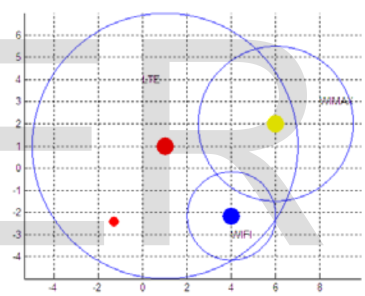

Figure 5.1: Mobile Terminal Connected to LTE Network

The simulation result in Figure 5.1 shows that VHO is not possible as no eligible network for VHO is found. The mobile terminals will Remain Connected to current LTE network. The MT no need to start VHO processes / calculate the quality factor any network.

Scenario 2:

The MT Starts moving to the coverage area of WI-FI. At this time the mobile terminal has two options it could automatically change it connection to WI-FI or remains connected to current LTE network.

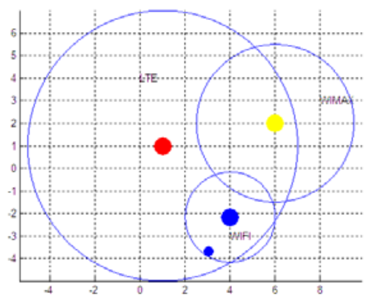

Figure 5.2: Mobile Terminal Connected to WI-FI Network

The current simulation value of quality factor based on equation 4.1, 4.2, 4.3, 4.4 and 4.5 are:

- Q_{LTE}=0.6778
- Q_{Wi-Fi} = 0.8456

The simulation result in Figure 5.2 shows that VHO is possible just to WI-FI since the quality factor Value of WI-FI being greater than LTE so it's best to handover from LTE to WI-FI for the better quality of service.

Scenario 3:

As MT Starts moving to the area where LTE, WI-FI and WiMAX coexist it could automatically change it connection to the available RATs either to WI-FI or WIMAX for the better quality of service.

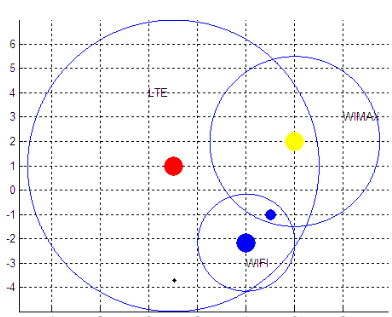

Figure 5.3: Mobile terminal Connected to WI-FI Network

The current simulation values of quality factor based on Equations (4.1, 4.2, 4.3, 4.4 and 4.5) are

- Q_{LTE}=0.9941
- Q_{WI-FI} = 0.9970
- Q_{WiMX} = 0.2216

The simulation result in Figure 5.3 shows that it is best handover to WI-FI since the Quality Factor Value of WI-FI being greater than LTE as well WiMAX so it's best to handover from LTE to WI-FI for the better quality of service.

Scenario 4:

The MT Starts moving to out of coverage area of LTE due to RSS going down, it could automatically change it connection to WIMAX to keep the session going.

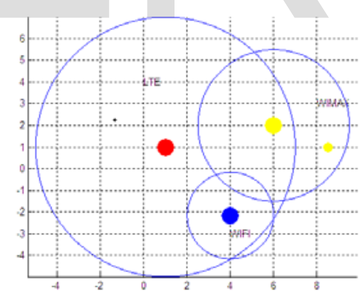

Figure 5.4: Mobile Terminal Connected to WiMAX Network

The simulation result in Figure 5.4 shows no other network including the current network is having minimum service quality better than threshold except WiMAX so no need to calculate the quality factor of each network jest handover to WiMAX to keep the session going on.

B. Simulation Result

i. User's Satisfaction

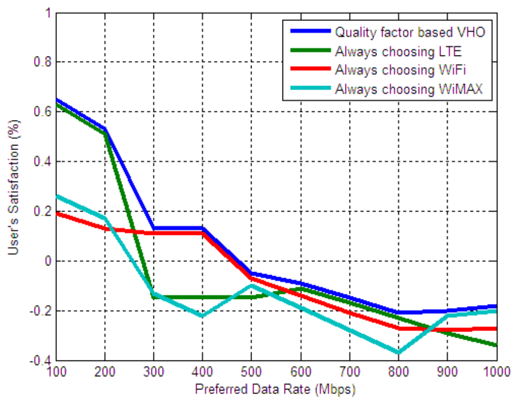

Figure 5.5: User's Satisfaction Based on Different Preferred Data Rate

In the above Figure 5.5, the average user's satisfaction is calculated using equation 4.9 for different value Preferred_data_rate and fixed value of Preferred_RSS, Preferred_Latency and Preferred_Energy_Consuption. As can be seen Quality factor based VHO achieved maximum user satisfaction by dynamically connecting to always the best network.

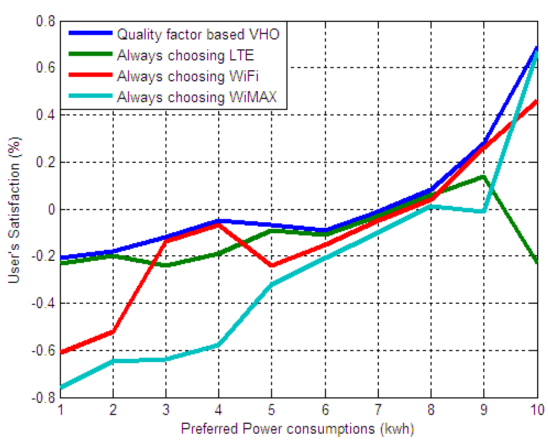

Figure 5.6: User's Satisfaction Based on Different Preferred Power Consumptions

In the above Figure 5.6, the average user's satisfaction is calculated using equation 4.9 for different value Preferred_Energy_Consuption and fixed value of Preferred_RSS, Preferred_Latency and Preferred_Data_Rate. As can be seen quality factor based VHO achieved maximum user satisfaction by dynamically connecting to always the best network.

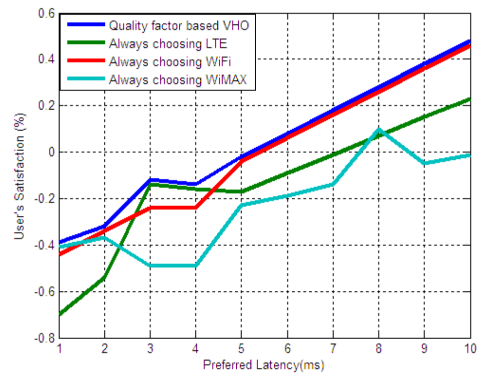

Figure 5.7: User's Satisfaction Based on Different Preferred Latency Time

In the above Figure 5.7, the average user's satisfaction is calculated using equation 4.9 for different value Preferred_Latency and fixed value of Preferred_RSS, Preferred_Energy_Consuption and Preferred_Data_Rate. As can be seen Quality factor based VHO achieved maximum user satisfaction by dynamically connecting to always the best network.

ii. Probability of Minimizing VHO Connection Failure

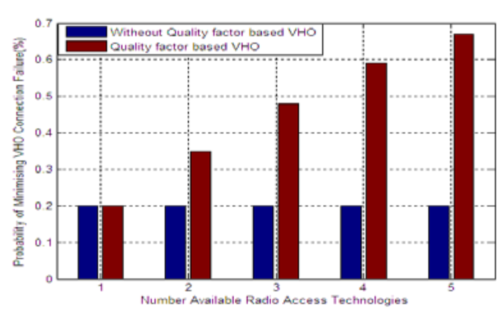

Figure 5.8: Comparison of Probability of Minimizing VHO Connection Failure (p=0.2)

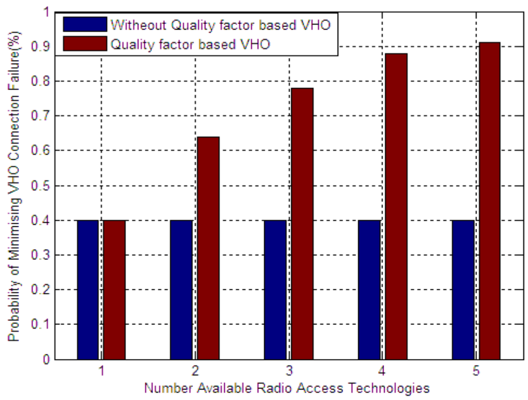

Figure 5.9: Comparison of Probability of Minimizing VHO Connection Failure (p=0.4)

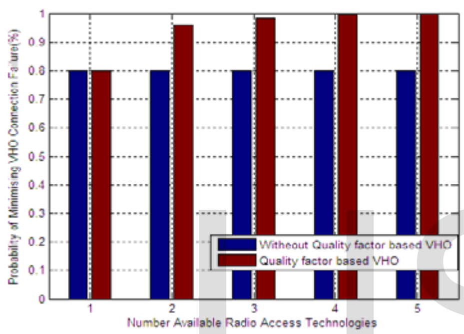

Figure 5.10: Comparison of Probability of Minimizing VHO Connection Failure (p=0.8)

C. Discussions

From the simulation results presented above the following observations can be made

Scenario 1

Reduce the power consumption and signaling cost of MT by avoiding unnecessary VHO process.

Scenario 2

Improve the quality of service due to VHO to Wi-Fi network and the probability of minimizing VHO connection failure is similar relative to previous works because there are only one target RAT are available. User satisfaction is improved by handover from LTE to Wi-Fi network.

Scenario 3

Improve the quality of service due to VHO to Wi-Fi network and as there is more than one RAT qualified to initiate the VHO, the probability of minimizing VHO connection failure is increased relative to previous works because there are two targets RAT for the checking resources. User satisfaction is improved by handover from LTE to Wi-Fi network.

Scenario 4

User satisfaction is improved by handover from LTE to WiMAX network and also avoids connection failure due to degradation of signal strength of MT.

Probability of Minimizing VHO Connection Failure

The probability of minimizing VHO connection failure is improved with the increasing number of RATs in RATs list of priority compared with previous works which is only selecting one target RAT for the checking resources. Also the probability of minimizing VHO connection failure is improved with the increasing the probability of available resources for any individual RAT

VII. CONCLUSION

The main aim of this thesis is to propose vertical handover decision mechanisms for LTE, WiMAX and Wi-Fi heterogeneous wireless networks which maximize user satisfaction level and minimize the probability of handover connection failure. To achieve this we have presented two vertical handover decision algorithms for selecting the best network as the handover target among available options based on four parameters received signal Strength, data rate, latency, and energy consumption. The second algorithms weight can be tuned according to the different Remaining battery percentage of MTs as well service type.

According to the results gathered from the simulation environment, the proposed algorithms maximized user satisfaction level from in terms of data rate, latency and energy consumption of mobile terminal and minimized the probability of vertical handover connection failure.

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