CHAPTER 3

SERVICE ADAPTIVE FUZZY MULTI-CRITERIA BASED INTELLIGENT VERTICAL HANDOVER DECISION ALGORITHM (IVHDA) FOR WIRELESS HETEROGENEOUS NETWORKS

3.1 INTRODUCTION

Cisco systems (Peter L 2014) estimates that global IP traffic in 2016 will be triple that of 2011 and this exponential growth on Internet usage would limit the quality of service provided to users. Qualcomm (2011) has stated that network operators are attempting to address this problem by upgrading their wireless WANs and deploying femto cells. However, these upgrades increase the cost of deployment on network operators and decrease the revenue on cost per megabyte. On the other hand, complementary technologies like Wi-Fi provide high data rate as compared to cellular networks with minimum pricing. This feature of Wi-Fi allows integration of Wi-Fi with UMTS network for seamless Wi-Fi offloading. This will reduce the number of active users on the cellular network in busy hours and gives better user experience with excellent quality of service. The development of IP based applications and mobile terminal with multiple network interfaces enable the mobile terminal to access the service from any network, at any time. Since wireless access networks differ from each other, their integration will enhance the user experience by choosing an optimal network and the
traffic can be offloaded from UMTS to Wi-Fi. But choosing an optimal network and initiating successful handover is a key problem. A fuzzy logic system for choosing the appropriate time to handover, and a multiple attribute decision making with context aware strategy for choosing the optimal network is proposed in this work.

3.2 LITERATURE SURVEY

This section reviews the related work that has been done on optimal network selection in a wireless heterogeneous networks environment. This section also presents a literature survey on various handover algorithms with their significance.

Qualcomm (2011) designed a connectivity engine that uses Dual Stack Mobile IP for sending selected IP traffic to particular interface with support for simultaneous 3G and Wi-Fi access. But the decision engine is based on received signal strength which has been proven to be not intelligent enough (TI e2e Support Community). This bottleneck is addressed in the proposed approach using fuzzy logic and multiple attribute decision making algorithms. Buburuzan (2009) presented a new handover model derived from the IEEE 802.21 standards which allows the seamless integration of broadcast technologies in a wireless heterogeneous environment. But the model needs major changes in the core architecture of cellular network. The proposed algorithm applies decision algorithm over the UMTS-WLAN integration architecture which does not require any change in the core architecture. X. Yan et al. (2010) presented a comprehensive survey of the VHD algorithms designed to satisfy QoS requirements.

Jin Chen et al. (2012) proposed a target network selection scheme based on bandwidth, dropping probability and cost parameters and the
parameters are placed in target visiting network to reduce the processing delay. The rapidly changing network conditions make the collected metrics unstable. They require frequent distribution of the collected metrics which increases the network traffic. The proposed algorithm handles this problem by processing the collected information locally in the mobile terminal itself. Kirsal et al. (2013) proposed a Markov model for UMTS-WLAN integration based on predefined policies. This model clearly differentiates requests originating in the cellular network, from requests being handed over from WLAN to the cellular network. This ensures that calls handed over from WLAN to cellular network are not handed over back to the WLAN. But the prediction of user movement in this algorithm makes it complicated to deploy it in a mobile terminal. Multiple attribute decision making algorithms is adopted to reduce unnecessary handover and call dropping probability in the proposed algorithm.

Mehbodniya et al. (2012) proposed a fuzzy logic based multiple attribute decision making which includes received signal strength, QoS parameters, and mobile velocity attributes with analytic hierarchy process as a weighting scheme. Finally the target network is selected based on TOPSIS ranking algorithm. Their proposed algorithm considers most of the essential parameters for handover decision making. But, it does not consider the load on the target network. There is a chance that the target network may get overloaded with new incoming clients. In such cases, this algorithm will trigger unnecessary handover. This bottleneck is handled in the proposed algorithm using fuzzy logic in the handover initiation phase to identify the most suitable network including the load capacity for handover decision making. Reddy et al. (2014) proposed an algorithm based on the dwell timer for eliminating ping pong effect by reducing the shadow fading effect. But, designing dwell timer for individual users based on their needs is not practically feasible. This bottleneck is handled in the proposed system by
designing an intelligent decision engine based on fuzzy logic and multiple attribute decision making for deciding when and to which network it has to handover.

Datta et al. (2012) proposed an analytic network process based optimum network selection algorithm using network traffic load, velocity of mobile station, reliability, data rate, and usage cost with the consideration of vehicular communication system. Lahby et al. (2012) and Kassar et al. (2008) proposed optimal network selection algorithm based on analytic network process and grey relational analysis. Maaloul et al. (2013) and Johnson et al. (2013) have presented a novel context aware vertical handover algorithm based on multiple attribute decision making and the results have shown that this algorithm avoids unnecessary triggered handovers. The imprecision of handover attributes in all these approaches may trigger unnecessary handover. The proposed algorithm handles the imprecision of attributes by incorporating fuzzy logic with multiple attributes decision making. Marquez et al. (2012) used geo-location, context information and route calculation for handover decision making to improve the performance of handover which requires high computational power to calculate geo-location based handover. There is no need to process entire available network list, because there may be a chance that some of the available network may have poor service quality (Ananthanarayanan 2014). In such cases, the processing of unsuitable network should be dropped at earlier stage itself. The proposed algorithm chooses a particular network for subsequent processing only if the received signal strength and link quality exceed the predefined threshold value.

This chapter presents a seamless vertical handover decision engine. The experimental setup and observations for analyzing the performance of the proposed algorithm are discussed. Detailed result analysis of our proposed algorithm is also presented.
3.3 PROPOSED METHODOLOGY

The proposed intelligent decision algorithm comprises of five phases including handover initiation, handover information gathering, handover decision, network selection, and handover execution. It handles the selection of optimal wireless network, authentication of mobile to the selected target network, and routing the selected traffic into the optimal wireless network. Unsuitable networks will be dropped at the handover initiation stage itself which avoids further processing. This helps to reduce the load on the decision engine and chooses the high QoS target network to enhance the user experience.

Figure 3.1 shows the architecture of the proposed algorithm. Once the optimal network is chosen, the mobile station is authenticated using enhanced fast iterative localized re-authentication protocol. The supervised traffic classifier (Naïve Bayes) is then used to classify the application traffic and the traffic is routed to appropriate wireless network interface based on user preference.

Figure 3.1 Architecture of Seamless Intelligent Vertical Handover Decision Algorithm (IVHDA)
Various blocks of the proposed IVHDA is discussed in this section.

### 3.3.1 Handover Initiation

Handover initiation phase collects available wireless networks by activating the wireless network interface periodically. This measurement interval \((T)\) is set based on the mobile velocity \((i.e)\) if the mobile velocity is high, then measurement interval should be relatively small for attaining quick response. Let the measurement period in the measurement interval be \(T_{mp}\). Then, the average measurement value is \(T_s=T/T_{mp}\). Forced handover is initiated by the system only if the mobile terminal experiences poor network connectivity with current network. Hence handover is initiated only if it satisfies equation 1.

\[
\frac{1}{T} \sum_{i} RSS_i \text{ & } LQI_i > (Threshold + Hystesis)
\]  

Handover can also be triggered based on the user policy and preferences for achieving ABC scheme. If the mobile velocity is higher than the threshold, then the handover request from a large coverage network to small coverage network is dropped. The membership values of received signal strength, link quality and mobile velocity are used in handover initiation for handling the imprecise data, thereby reducing unnecessary processing.

### 3.3.2 Handover Information Gathering

Handover information gathering phase is triggered only if handover is initiated from the handover initiation phase. The input parameters are signal strength indicator\((S)\), load capacity \((L)\), signal to noise interference ratio \((R)\), security \((SS)\), mobile velocity \((M)\), service cost \((C)\), battery power
requirements ($B$), and network latency ($NL$). The fitness/objective function in equation 2 indicates the high received signal strength, high load capacity, high signal-to-noise-plus-interference ratio, high security, high mobile velocity, low service cost, low battery power requirements, and low network latency (Yaw Nkansah-Gyekye, and Johnson I.Agbinya 2007).

\[ F(x) = \sum_{i=1}^{5} W_i N(X_i) + \sum_{j=1}^{3} W_j N(Y_j) \]  

Where fitness function $F(x) = f(S, L, R, SS, M, 1/C, 1/B, 1/NL)$, and $W, N(X), N(Y)$ indicate the corresponding weights, normalized value of maximization and minimization of the attributes respectively. Based on the objective, the handover attributes are grouped as maximization ($S, L, R, SS, M$) and minimization ($C, B, NL$) attributes in fitness function. Equation 3 represents the matrices $X$ and $Y$ that indicate the maximization attributes and the minimization attributes respectively from the all available networks before normalization. $N_1, N_2, \ldots, N_n$ indicates the available network set in equation 3.

\[
X = \begin{bmatrix}
N_1 & a_{11} & a_{12} & a_{13} & a_{14} & a_{15} \\
N_2 & a_{21} & a_{22} & a_{23} & a_{24} & a_{25} \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
N_n & a_{n1} & a_{n2} & a_{n3} & a_{n4} & a_{n5}
\end{bmatrix}, \\
Y = \begin{bmatrix}
N_1 & a_{16} & a_{17} & a_{18} \\
N_2 & a_{26} & a_{27} & a_{28} \\
\vdots & \vdots & \vdots & \vdots \\
N_n & a_{n6} & a_{n7} & a_{n8}
\end{bmatrix}
\]

3.3.3 **Handover Decision Algorithms**

The collected input from different networks are in a different scale and hence need to be normalized to make it useful. The collected attributes from the network is passed into a fuzzifier for normalization. Service cost, battery power requirements, and network latency are normalized in terms of minimum normalization function and other values are normalized with
respect to the maximum normalization function. The values are normalized in the range of 0 to 1 by mapping into membership functions.

3.3.3.1 Fuzzifier

The collected input parameters are fed into the fuzzifier and transformed into fuzzy sets. The transformation is generated by mapping into membership functions. All attributes are mapped into three fuzzy sets namely poor, medium, and strong. The given matrix $X, Y$ is normalized through the normalization function listed in equation (4) and combined into a single matrix called $N(X,Y)$ listed as equation (5). The attribute $a_{ij}$ indicates the normalized value of the given attribute.

$$ N(X) = \frac{X}{X_{\text{max}}}, \quad N(Y) = \frac{Y_{\text{min}}}{Y} \quad \text{(4)} $$

$$ N(X,Y) = \begin{bmatrix} S & L & R & SS & M & C & B & NL \\ N_1 & a_{11} & a_{12} & a_{13} & a_{14} & a_{15} & a_{16} & a_{17} & a_{18} \\ N_2 & a_{21} & a_{22} & a_{23} & a_{24} & a_{25} & a_{26} & a_{27} & a_{28} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ N_n & a_{n1} & a_{n2} & a_{n3} & a_{n4} & a_{n5} & a_{n6} & a_{n7} & a_{n8} \end{bmatrix} \quad \text{(5)} $$

The membership values are obtained from equation 5.

3.3.3.2 Weight Assignment

The next step is to calculate attribute weight by Relative matrix ($Rm$) which is based on the type of application or service. The calculated weights using relative matrix (equation 6) and membership value of the attributes (equation 5) are used to calculate fitness factor of the target network. The relative matrix ($Rm$) indicates the relative importance of one attribute with another. If both the attributes have equal importance, then the relative matrix value is 1. If it is having more importance compared to another attribute, then
the relative matrix value is 9. The intermediate values indicate the level of importance. For example, voice chat needs low latency network than high data rate network which has high delay. For simplicity, only few attributes are shown in Rm. The relative matrix is constructed for interactive services where load capacity and network latency have more importance than the received signal strength.

\[
Rm = \begin{bmatrix}
S & L & \ldots & NL \\
S & 1 & 3 & \ldots & 3 \\
L & 3 & 1 & \ldots & 9 \\
\ldots & \ldots & \ldots & \ldots & \ldots \\
NL & 5 & 7 & \ldots & 1 \\
\end{bmatrix}
\]  

(6)

### 3.3.3.3 Fitness Function

The given normalized fuzzy sets indicate the membership values. These values are fed into fitness function to calculate the network score. The fitness function is the product of weights of the attributes and membership values of the attributes (equation 7).

\[
F(X) = \sum_{i=1}^{8} W_i N(X_i, Y_i)
\]  

(7)

### 3.3.4 Network Selection

The network selection phase includes two steps. The first step is to get the fitness factor of all the available networks and the second step is to find an optimal network using Grey Relational Analysis (GRA). GRA does not attempt to find the best solution, but provides an appropriate solution for real world problems. GRA uses ranking for evaluating the candidate networks based on the weights and selects the one available network with the highest
ranking. GRA takes the user preferred network and the fitness factor (equation 7) as the input and based on that it ranks the available wireless networks. The network with highest ranking is chosen as an optimal network.

3.3.5 Handover Execution

Once the optimal network is identified in the handover decision phase, the handover execution phase applies make-before-break handover scheme and initiates the regular authentication and mobile IP registration to complete handover process.

3.4 EXPERIMENTAL SETUP

Our proposed approach for vertical handover is implemented in Ubuntu 13.04 based machine for measuring efficiency and effectiveness of our proposed algorithm. For the implementation of fuzzy and grey relational analysis, standard tools jFuzzyLogic_v3.0 (Cingolani et al. 2012)and JGRA (JAVA based Grey Analysis) are used respectively. The input parameters to decision engine are signal strength, quality of service, service cost, power requirements, mobile velocity, available data rate, network latency and user preferences. The decision algorithm uses common parameters to support integration of all high data rate technologies.

Table 3.1 shows the experimental set up for analyzing the performance of our proposed approach. The experimental set up includes two Wi-Fi AP kept at a distance of 20m and a laptop connected to cellular network (High Speed Packet Access connection). Wi-Fi 1 and 2 are set to operate in 802.11n and 802.11b mode respectively. Wi-Fi 1 operates in channel 11 (auto mode) and Wi-Fi 2 operates in channel 8 (manual mode).
Table 3.1  Experimental Setup for Performance Analysis of Decision Engine

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decision Engine</td>
<td>Fuzzy with Grey Relational Analysis</td>
</tr>
<tr>
<td>Fuzzy Logic Implementation</td>
<td>jFuzzyLogic_v3.0</td>
</tr>
<tr>
<td>Grey Relational Analysis</td>
<td>JGRA</td>
</tr>
<tr>
<td>Wi-Fi 1</td>
<td>Virtual Wi-Fi AP on Samsung Tab2 P3100</td>
</tr>
<tr>
<td>Wi-Fi 2</td>
<td>NETGEAR</td>
</tr>
<tr>
<td>Cellular Network</td>
<td>BSNL on Huawei Mobile Broadband E303s</td>
</tr>
<tr>
<td>Clients Connected to Wi-Fi 1</td>
<td>1</td>
</tr>
<tr>
<td>Clients Connected to Wi-Fi 2</td>
<td>4</td>
</tr>
</tbody>
</table>

3.4.1  Device Interoperability

The software defined networking approach is used for handling device interoperability. The decision engine manages the network services through lower level of functionality by decoupling the wireless access technology into control plane and data plane. The control plane selects the interface to route the traffic and the data plane will route the traffic into the selected interface. To support interoperability between devices, most of the data cards are studied and connect, redialing, and disconnect features are extracted. These features are coded using scripts and used in the decision engine to obtain handover metrics independent of devices. Our proposed approach supports different data cards including Huawei E series and Reliance CDMA data cards on most of the carriers.
3.5 OBSERVATIONS

Five different networks have been found during network discovery and used to analyze the performance of the proposed approach. During periodic scan, the handover initiation phase identifies two Wi-Fi AP with good QoS (equation 1). The handover initiation phase triggers handover request to the handover information gathering phase. The handover metrics are collected and membership values of the attributes calculated for Wi-Fi 1, UMTS 1, and Wi-Fi 2. The findings of the proposed IVHDA are depicted at Table 3.2.

<table>
<thead>
<tr>
<th>Handover Attributes</th>
<th>Available Networks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wi-Fi 1</td>
</tr>
<tr>
<td>Remaining battery capacity (B)</td>
<td>0.7</td>
</tr>
<tr>
<td>Received signal strength (S)</td>
<td>0.8</td>
</tr>
<tr>
<td>SINR (R)</td>
<td>0.9</td>
</tr>
<tr>
<td>Load capacity (L)</td>
<td>0.8</td>
</tr>
<tr>
<td>Network latency (NL)</td>
<td>0.2</td>
</tr>
<tr>
<td>Service cost (C)</td>
<td>0.3</td>
</tr>
<tr>
<td>Mobile velocity (M)</td>
<td>0.3</td>
</tr>
<tr>
<td>Security (SS)</td>
<td>0.8</td>
</tr>
</tbody>
</table>
Figure 3.2  Membership Values of Handover Metrics and Handover Probability

Figure 3.2 shows the membership values of the selected handover metrics including battery status (bstatus), signal strength (rssi), mobile velocity, load capacity, link quality, and handover probability of available network. The weights of handover attributes are calculated using relative matrix (equation 6). Each application profile (Interactive, Non-interactive, and Bulk) has its own relative matrix and the associated weights are tabulated in Table 3.3.
Table 3.3  Preferred Weights for Application Profiles

<table>
<thead>
<tr>
<th>Handover Attributes</th>
<th>Application Profiles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Interactive</td>
</tr>
<tr>
<td>Remaining battery capacity (B)</td>
<td>0.154</td>
</tr>
<tr>
<td>Received signal strength (S)</td>
<td>0.105</td>
</tr>
<tr>
<td>SINR (R)</td>
<td>0.168</td>
</tr>
<tr>
<td>Load capacity (L)</td>
<td>0.126</td>
</tr>
<tr>
<td>Network latency (NL)</td>
<td>0.092</td>
</tr>
<tr>
<td>Service cost (C)</td>
<td>0.088</td>
</tr>
<tr>
<td>Mobile velocity (M)</td>
<td>0.135</td>
</tr>
<tr>
<td>Security (SS)</td>
<td>0.132</td>
</tr>
</tbody>
</table>

The fitness function is calculated using membership value of the retrieved attributes and their associated weights (Equation 7). The weights are calculated based on the type of service to be used. The following calculations are shown for fitness of the available networks to bulk application profiles.

**Fitness** \(_{\text{Bulk (network)}}\) = 0.154 * (Remaining battery capacity) + 0.105 * (Received signal strength) + 0.168 * (SINR) + 0.126 * (Load capacity) + 0.092 * (Network latency) + 0.088 * (Service cost) + 0.135 * (Mobile velocity) + 0.132 * (Security)

**Fitness** \(_{\text{Bulk (Wi-Fi 1)}}\) = 0.154 * (0.7) + 0.105 * (0.8) + 0.168 * (0.9) + 0.126 * (0.8) + 0.092 * (0.2) + 0.088 * (0.3) + 0.135 * (0.3) + 0.132 * (0.8) = 0.6347

**Fitness** \(_{\text{Bulk (UMTS 1)}}\) = 0.154 * (0.7) + 0.105 * (0.4) + 0.168 * (0.6) + 0.126 * (0.9) + 0.092 * (0.7) + 0.088 * (0.3) + 0.135 *(0.3) + 0.132 *(0.6) = 0.5745
Figure 3.3 Ranking of Available Networks in GRA

The handover factor and user preferences are given as the input to the grey relational analysis for calculating the rank for the available networks. Figure 3.3 shows the ranking of Wi-Fi 1, UMTS 1, and Wi-Fi 2. From the analysis, it is clear that Wi-Fi 1 is the most suitable network for handover among all available networks.

3.6 RESULT ANALYSIS

3.6.1 Handover Triggering

There are two possibilities to initiate the handover. Forced handover is initiated by the system only if the mobile terminal experiences poor network connectivity with current network. Handover can be triggered based on the user policy and in some cases, policy based handover is referred as Wi-Fi offloading. During peak hours, the bulk data is routed using carrier Wi-Fi and the proprietary services like voice call and value added services are routed through cellular network. If the mobile velocity is higher than the average mobility, then the handover request from large coverage network to small coverage network is dropped. The imprecision of received signal strength, link quality, and mobile velocity is handled through fuzzy logic.
membership function. Hence the unsuitable network is eliminated at the handover initiation phase itself. The best suitable offloading network is chosen based on its load capacity, service cost, and network latency using multiple attribute decision making.

The intelligent decision engine triggers the handover to Wi-Fi 1 when the laptop moves in the coverage of Wi-Fi 1 and Wi-Fi 2 network, thereby reducing the handover to Wi-Fi 2. Decision engine chooses Wi-Fi 1, because it supports high data rate as compared to Wi-Fi 2 that operates on channel 11 which is a non-interfering channel, and has the load of only one client.

### 3.6.2 Handover Delay

![Comparison of Handover Delay in Vertical Handover Schemes](image)

**Figure 3.4** Comparison of Handover Delay in Vertical Handover Schemes

Figure 3.4 shows the handover delay in various vertical handover schemes. The handover delay of FMIPv6, mSCTP, MIH, SIP Bicast is referred from (Prince Edward and Sumathy 2010). It clearly shows that our proposed
intelligent vertical handover decision algorithm (IVHDA) performs better in terms of handover delay as compared to other major schemes.

3.6.3 Packet Loss Analysis

Figure 3.5 shows the packet loss analysis of our proposed algorithm. The Wi-Fi offloading is enabled thrice to analyze the performance of our proposed algorithm and it chooses Wi-Fi 1 in all the three cases and the packet losses are analyzed using ping command in Ubuntu. On an average, the proposed algorithm has packet loss percentage around 0.7%.

3.6.4 Call Dropping and Call Blocking

Call dropping and blocking probability are the most important factors in traffic usage during handover. The experiment was conducted with a total number of 500 calls, calling rate being 20 /hour, and call holding time was 120 seconds. It was observed that the total number of blocked calls were 3 and dropped calls were 2 in this scenario. Table 3.4 shows blocking probability and drop call rate in busy hours along with varying handovers.
### Table 3.4 Call Blocking Probability and Drop Call Rate

<table>
<thead>
<tr>
<th>Number of Handovers</th>
<th>Blocking Probability</th>
<th>Drop call rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handover &lt; 3</td>
<td>3/494</td>
<td>3/500</td>
</tr>
<tr>
<td>Handover &lt; 5</td>
<td>3/494</td>
<td>3/500</td>
</tr>
<tr>
<td>Handover &lt; 7</td>
<td>2/500</td>
<td>4/500</td>
</tr>
</tbody>
</table>

Blocking Probability = (Number of lost calls) / (Total number of offered calls)

Drop call rate = (Number of dropped calls / No of call attempts)

Blocking Probability in busy hours = (3 / 494) = 0.00607

Drop call rate in busy hour = (2/500) = 0.004

#### 3.6.5 Comparison of Vertical Handover Algorithms

Performance of the proposed algorithm is compared with existing popular vertical handover algorithms.
Figure 3.6 Evaluation Model of Vertical Handover Algorithms

Table 3.5 Comparison of Vertical Handover Algorithms

<table>
<thead>
<tr>
<th>Name</th>
<th>Bandwidth</th>
<th>Delay</th>
<th>Jitter</th>
<th>PER</th>
<th>Cost</th>
<th>Criticality</th>
</tr>
</thead>
<tbody>
<tr>
<td>IVHDA</td>
<td>10</td>
<td>10</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>97.8987</td>
</tr>
<tr>
<td>TOPSIS</td>
<td>10</td>
<td>8</td>
<td>9</td>
<td>8</td>
<td>9</td>
<td>97.8474</td>
</tr>
<tr>
<td>SAW</td>
<td>10</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>9</td>
<td>97.6802</td>
</tr>
<tr>
<td>ELECTRE</td>
<td>10</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>9</td>
<td>97.6802</td>
</tr>
<tr>
<td>VIKOR</td>
<td>2</td>
<td>9</td>
<td>8</td>
<td>9</td>
<td>8</td>
<td>36.3819</td>
</tr>
</tbody>
</table>

Figure 3.6 and Table 3.5 shows the comparison of various vertical handover algorithms (run on a simulator Evaluation of vertical handover algorithms – evomha) including SAW, TOPSIS, ELECTRE, VIKOR and our proposed intelligent vertical handover decision algorithm (IVHDA) in terms of bandwidth, delay, jitter, packet error rate (PER) and cost. The performance analysis shows that IVHDA performs better than other leading algorithms in terms of delay and packet error rate.
3.7 CONCLUSION

Our proposed approach in vertical handover decision algorithm using fuzzy logic-multiple attributes with context aware strategy enables a mobile terminal to make proactive decision based on user preferences and QoS parameters. The performance analysis demonstrates the effectiveness of the proposed algorithm in terms of minimal packet loss (< 1%), running time (2ms), high bandwidth and efficient resource utilization based on the application requirements. The proposed approach fulfills QoS requirements of audio, video, and data in terms of packet loss, round trip time, and handover delay as recommended by Cisco System. The performance analysis shows that the proposed algorithm maintains active connections in UMTS, WLAN interface simultaneously to offer optimal connectivity, minimal service cost to the user, load balancing and it is capable of forwarding data packets to appropriate attachment points to maximize battery life. The Naïve Bayes classifier has accuracy of 88.28% in classifying real time application traffic of 21453 samples with classification time of 0.08s. It routes 71.99% of application traffic using Wi-Fi network and 28.01% of application traffic using UMTS network to reduce the service cost and network load on the cellular operator. It is observed that the average handover delay for the experiment was 25-30ms under good network conditions and it reduces the call dropping rate (<0.004), blocking probability (<0.00607) as well as unnecessary handover in heterogeneous wireless networks.

Our proposed work can be extended to automatically classify the application traffic using appropriate unsupervised learning algorithm to choose optimal network for the specific type of traffic. Automatic traffic classification using machine learning algorithm for policy based routing in UMTS-WLAN interworking is proposed and discussed in the next chapter. There is a possibility of illegitimate AP to participate in this scheme and which adds
unnecessary delay due to the signalling exchanged with the illegitimate AP. An enhancement to the fast iterative localized re-authentication protocol for UMTS-WLAN interworking to proactively detect the intruder AP and to avoid further communication with the illegitimate AP is proposed and discussed in chapter 5.