CHAPTER 6

CO-OPERATIVE DECISION MAKING FOR LOAD BALANCING (CDMLB) IN WIRELESS HETEROGENEOUS NETWORKS

6.1 INTRODUCTION

In a wireless heterogeneous networks, vertical handover decision algorithm making use of fuzzy logic system for choosing the appropriate time to handover and multiple attribute decision making with context aware strategy for choosing the optimal network is proposed in the previous chapters along with traffic classification. Performance of the proposed algorithm can be improved by incorporating cooperative decision making algorithm for load balancing; collaborative offloading to increase the possibility of offloading, envy free fair division for efficient bandwidth allocation; and proxy agent to reduce connection block-outs during vertical handover. An algorithm for co-operative decision making for load balancing based on cake cutting concept is proposed in this chapter.

6.2 LITERATURE SURVEY

A number of proposals have been made for vertical handover decision algorithms. Important algorithms are already discussed in
the previous chapters. Existing algorithms related with load balancing in heterogeneous networks are discussed in this section.

Ning Ding et al. (2013) presented collaborative Wi-Fi based offloading solution for energy conservation in smart phones. It collaborates cellular operators, Wi-Fi providers and smart phone users and offloads the mobile data to the nearest Access Point (AP) to conserve energy. However, this approach requires mobility prediction and localization algorithm for locating nearest AP, resulting in a considerable expenditure of energy to be spent on localization process. The error in localization triggers unnecessary handover and network scannings. Kyunghan Lee et al. (2013) presented a quantitative study on the performance of offloading through Wi-Fi networks and it has been found that offloading saves 55% of battery power of smart phones. The theoretical framework estimates that the average performance of offloading in a given Wi-Fi deployment condition reduces the energy consumption. Dae Sun kim et al. (2013) presented mobile velocity based offloading between 3GPP and non-3GPP access networks to reduce unnecessary network scannings. The variation in mobile velocity brings in uncertainty in decision making. Hence, along with mobile velocity, other factors like service cost, network latency, and user preferences etc., should be considered.

Picone et al. (2013) presented an experimental analysis of mobile data offloading using Android application. Li Y et.al (2013) presented a mathematical framework to study offloading under realistic assumptions. The survey includes heterogeneity of mobile data, subscribing interest of mobile users, and AP limitation in offloading. The authors used real mobility traces in simulation for testing Disruption Tolerant Networking. This model does not consider the network load on the target wireless network. Yongmin et al.
(2011) presented a quantitative survey and strategic solution for mobile data offloading and network planning.

Mehbodniya et al. (2012) proposed a fuzzy logic based multiple attribute decision making method, 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 triggers unnecessary handover. 3GPP ANDSF and Hotspot 2.0 are the popular connection managers developed by 3GPP and Wi-Fi Alliance respectively for autonomous network discovery and connection (Alcatel-Lucent 2012). It is observed that these smart connection managers enable the mobile terminal to make decision based on network policy and received signal strength. But these popular connection managers do not consider the location information, access network type, and AP load while making a decision. Our proposed algorithm considers all the parameters left out in these smart connection managers and uses cooperative decision making to improve the selection of network and reduce the signaling for handover processing.

To summarize, a hybrid system with a combination of fuzzy logic system for choosing the appropriate time to handover, multiple attribute decision making with context aware strategy for choosing the optimal network, envy free-fair division algorithm for efficient resource utilization, and cooperative decision making for load balancing is proposed in this chapter.

6.3 PROPOSED METHODOLOGY

The proposed algorithm comprises of cooperative decision based optimal network selection, proxy agent for reducing connection block-outs, and envy free fair division algorithm for efficient bandwidth allocation. It
handles the selection of optimal wireless network, authentication of a mobile to the selected target network, and routing the selected traffic into the optimal wireless network. Any unsuitable network gets 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.

6.3.1 Handover Initiation

The handover initiation phase is adopted from the proposed work discussed in the section 3.3.1. The subsequent network ranking and cooperative decision making phases triggered only if handover is initiated from the Handover Initiation.
The architecture of cooperative decision making for load balancing is shown in Figure 6.1

6.3.2 Network Ranking

This phase includes information gathering, handover decision making algorithms, cooperative decision making, and handover execution
phase. It mainly involves in collecting the network information and use those information for ranking.

6.3.2.1 Information Gathering

Handover information gathering phase is triggered only if handover is initiated from the handover initiation phase. A software agent creates optimal time for activating the wireless interface to have a periodic scan. Scanning time and interval is based on the mobile velocity. If the mobile velocity is high, then measurement interval should be relatively small for attaining quick response. If the mobile velocity is higher than the threshold, then the handover request from a large coverage network to small coverage network is dropped. It collects the received signal strength (RSS), link quality indicator (LQI), security, mobile velocity, network load, remaining battery capacity, application used, preferred network, and QoS requirements.

6.3.2.2 Handover Decision Algorithms

6.3.2.3 Fuzzifier

The collected inputs from different networks are in a different scale and hence needs to be normalized to make it useful. The fluctuations and imprecision in the collected attributes create uncertainty in decision making. Hence, 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 the balance parameters 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. Each attribute has the membership values in the fuzzy
sets of “poor”, “good”, and “excellent”. The membership of attributes in the “excellent” fuzzy set is taken as the input for Grey Relational Analysis (GRA).

Collect handover attributes from the network in the Selected Network list

$$SN = \{SN_i | i \in I\}$$

Calculate membership values for all handover attributes of the network

$$For \ i = 1 \ to \ a_n \ in \ SN_i$$

6.3.2.4 Attribute Weights

The weights of attribute are calculated by Relative matrix (Rm) as mentioned in section 3.3.3.2

6.3.2.5 Grey Relational Analysis

GRA does not attempt to find the best solution, but provides an appropriate solution for real world problems. GRA takes the user preferred network, membership values, and the attribute weights for evaluating the available networks.

Feed membership values (M) and attribute weights (W) for GRA ranking.

Form initial matrix using upper and lower bound, then calculate the weighted matrix (WM)

$$W_{mi} = M_i * W_i$$

Weighted matrix is used for calculating grey relation co-efficient and grey degree. The grey degree is referred as network rank. GRA finds Grey Relation Co-Efficient and based on that it ranks the available wireless networks. The network that has ranked more than 0.5 has been considered for
network selection and stored in candidate list. The network with highest ranking in the candidate list is chosen as an optimal network.

6.3.3 Cooperative Decision Making and Handover Execution

Co-operative decision making algorithm is integrated in the proposed system to provide load balancing. Work flow and steps involved in the proposed algorithm is discussed in the following section.

6.3.3.1 Proposed algorithm for Enabling Cooperative Decision Making for Load Balancing in Integrated Wireless Heterogeneous Networks

**Step 1:** If MT is connected to UMTS & experiences poor quality || user/network policy based handover

Then

**Step 2:** If \( V_{MT} < \) Mobility Threshold (m/s)

Initiate network scanning for S seconds

For i=0 to S

Let Available network set be \( N \) {Candidate set};

\[ N_1, N_2, \ldots, N_n \]

\[ N_i \cap N_j = \emptyset \text{ for } i=j \]

End

**Step 3:** Collect RSSI & LQI for \( T_n \) seconds

Let Time duration be \( T_n \);

For i=1 to N

\[ ARSSI_{WLAN} = \frac{1}{T_n} \sum_{i=1}^{n} RSS_{i} \]
Let network with good QoS be SN;

**Step 4:** Collect the network that has good average RSS and LQI and stores in Selected Network list (SN)

For i=1 to N

If \((\text{ARSS}_{\text{WLAN}_i}) \| (\text{ALQI}_{\text{WLAN}_i}) > \text{Threshold}\) then

SN \{…\} \leftarrow N_i

Else

**Step 5:** Remove the network has poor QoS

Remove N_i from set N

End

**Step 6:** Collect handover attributes from the network in the Selected Network list

For i=1 to \(SN_n\)

\(SN = \{SN_i | i \in I\}\)

**Step 7:** Calculate membership values for all handover attributes of the network

For i=1 to \(a_1\) in \(SN_i\)

\[ M = \frac{a_i}{\max \{n | 1 \leq i \leq n\}} \]

End

End

**Step 8:** Find associate attribute weights

\(W = \{w_1, w_2, \ldots, w_n\}\)

**Step 9:** Feed membership values and attribute weights for GRA ranking

Apply GRA
Let Upper bound is 1 and Lower bound is membership value \( M \)

Attribute weights \( W \);

**Step 10:** Form initial matrix using upper and lower bound then calculate the weighted matrix

\[ WM_i = M_i \times W_i \]

Calculate grey relation co efficient

\[ \gamma_{x} = \gamma(x_{o}(k), x_{i}(k)) = \min_{k} \min_{i} \left| x_{o}(k) - x_{i}(k) \right| + \frac{\xi}{\max_{k} \max_{i} \left| x_{o}(k) - x_{i}(k) \right|} \]

Calculate grey degree

\[ \gamma(X_0, X_i) = \prod_{k} \gamma(x_{o}(k), x_{i}(k)) \]

Where \( x(k) \) indicates membership values, \( n \) indicates number of attributes

End

**Step 11:** Select network \( SN_i \) with highest ranking \( \gamma(X_0, X_i) \)

**Step 12:** Initiate cooperative decision making

Send probe request to the network \( SN_i \) with highest ranking

If load on the network \( SN_i \) with highest ranking is below threshold

Then network accepts the probe request and follows subsequent authentication procedures

Else the selected network sends the other available network which has minimum load for mobile terminal to choose anyone from the available list.

**Step 13:** Initiates software proxy agent for reducing connection block outs.

End

Once the mobile terminal finds an optimal network, then it sends probe request to the Wi-Fi AP. Based on network load at the instant, the Wi-Fi AP may accept or deny the probe request. It keeps the Wi-Fi AP always lightly loaded and offers high QoS to the connected users. Wi-Fi AP uses maximum
try request from a client to avoid DoS attack. If Wi-Fi AP denies the probe request, then mobile terminal tries to connect to the optimal network that has next highest ranking. Two different approaches including AP associated handover and mobile terminal assisted handover have been used.

6.3.3.2 Mobile Terminal Associated Handover

Whenever the mobile terminal finds an optimal network, it initiates probe request to that selected network. The network checks the current load and if the load is above a threshold, then the request is rejected by AP, else the subsequent actions including authentication and association are initiated.

![Mobile terminal associated handover diagram](image)

**Figure 6.2** Mobile terminal associated handover
Figure 6.2 illustrates the work flow involved in mobile terminal associated handover. The maximum try for connection establishment is set to three for optimizing the handover processing, handover delay, and energy spent on processing. Mobile assisted mode increases the delay and energy consumption if the load of all the AP are above threshold.

### 6.3.3.3 AP Assisted Handover

The load of the AP is broadcast at every 60 seconds to its neighbors. If an AP is overloaded at the time of receiving probe request, then the SSID of the AP that has the minimum load is suggested. It reduces the processing burden of mobile terminal by distributing the handover processing to AP. Since the AP is powered through power stations, the energy consumption is negligible.
Figure 6.3  AP Assisted Handover

Figure 6.3 illustrates the work flow associated with AP assisted handover.

6.3.4    Proxy for Reducing Connection Block-outs during Handover

Connection block-outs have direct impact on packet loss during handover, and hence it should be minimized to make seamless experience during handover.
The proposed algorithm illustrated in figure 6.4 uses proxy agents to reduce the connection block outs. Software proxy agents are installed in the mobile terminal and it acts as an intermediate between the mobile terminal and internet. The request from the mobile terminal is forwarded to the software proxy agents, which forward the request to the internet. Hence any change in IP address due to handover will not affect the connection on the mobile terminal.

6.3.5 Envy Free- Fair Division Algorithm

Fair allocation of bandwidth in wireless heterogeneous networks is an interesting problem in vertical handover. Wi-Fi AP allocates the bandwidth to attached devices without considering their actual requirements. This results in the under-utilization of allotted bandwidth. The radio spectrum is a finite and valuable resource that needs to be allocated properly and used efficiently. Envy free fair division algorithm is used to achieve a good tradeoff between fairness and throughput. Envy free fair division algorithm collects the minimum bandwidth need from all the users and allocates fairly.

Let the available data rate be $X$, and a group of users denoted as $MT$ competing for data rate be $n$. Hence the fair division will be $X = X_1 \cup X_2 \ldots \cup X_n$. 
Here X is an infinite set representing a divisible resource called data rate. The division of data rate is heterogeneous, because each user wants different level of QoS. The division of heterogeneous divisible resource is referred as fair division. Since different mobile terminal users prefer different QoS, only subjective fairness division is possible (Fair division cake cutting problem) (Fair division calculator).

Envy free: Each user gets a share of at least as much as all other shares. The user i gets a share greater than or equal to user j.

\[ MT_i(X_i) \geq MT_j(X_j) \forall i \text{ and } j; i \neq j \]

6.3.5.1 Envy Free algorithm

**Step 1:** Let n be number of users, S be the available bandwidth, and \( \alpha \) be the number of divisions.

\[ \alpha : \{1,...,n\} \rightarrow 2^s \]

\[ S_1,\ldots,S_n \in S \]

**Step 2:** Two users will not be allocated on the same frequency band

\[ S_i \cap S_j = \emptyset \]

**Step 3:** The sum of bandwidth is equal to the total bandwidth

\[ \bigcup_i S_i = S \]

**Step 3:** Every user thinks that he has been allocated with more bandwidth than others

\[ \forall i, j \quad \mu_i(S_i) \geq \mu_j(S_j) \]

\[ \mu_i : 2^s \rightarrow [0,1] \]

**Step 4:** Assume X, Y as frequency bands allocated for two users
\[X, Y \subseteq S : X \cap Y = \phi\]

\[\mu_i(X \cup Y) = \mu_i(X) + \mu_i(Y)\]

### 6.4 EXPERIMENTAL SETUP

The proposed approach has been implemented in Ubuntu 13.04 based machine and for the implementation of fuzzy and grey relational analysis; standard tools jFuzzyLogic_v3.0 (Cingolani et al. 2012) and JGRA (JAVA based Grey Relational Analysis) are used respectively. The input parameters to decision engine are RSS, LQI, security, mobile velocity, network load, remaining battery capacity, the application used, preferred network, and QoS requirements.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test bed for Decision Engine</td>
<td>Wi-Fi AP, Ubuntu based Client</td>
</tr>
<tr>
<td>Decision Engine</td>
<td>Fuzzy with Grey Relational Analysis</td>
</tr>
<tr>
<td>Fuzzy Logic &amp; GRA</td>
<td>jFuzzyLogic_v3.0, JGRA</td>
</tr>
<tr>
<td>Cooperative Decision</td>
<td>Distributed Wi-Fi AP with Mobile Terminal</td>
</tr>
<tr>
<td>Test Bed for Cooperative Decision</td>
<td>Simulated using Java-Socket Programming</td>
</tr>
<tr>
<td>Encryption</td>
<td>AES with salting</td>
</tr>
<tr>
<td>Bandwidth Allocation</td>
<td>Envy free- Auto Sperner fair division</td>
</tr>
</tbody>
</table>
The experimental set up for analyzing the performance of our proposed approach is tabulated at Table 6.1. Since the cooperative decision making and collaborative offloading require changes in the firmware of AP, the proposed scheme is tested in a simulated environment. Wi-Fi AP and clients are simulated using Java based socket programming.

### 6.5 OBSERVATIONS

Seven different networks have been found during network discovery and are used to analyze the performance of our proposed approach. The findings are depicted at Table 6.2.

<table>
<thead>
<tr>
<th>Handover Parameters</th>
<th>Membership Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>RSSI</td>
<td>Network 1 0.8, Network 2 0.7, Network 3 0.7, Network 4 0.8, Network 5 0.7</td>
</tr>
<tr>
<td>LQI</td>
<td>Network 1 0.2, Network 2 0.4, Network 3 0.5, Network 4 0.4, Network 5 0.8</td>
</tr>
<tr>
<td>Security</td>
<td>Network 1 0.3, Network 2 0.5, Network 3 0.6, Network 4 0.6, Network 5 0.9</td>
</tr>
<tr>
<td>Mobile Velocity</td>
<td>Network 1 0.4, Network 2 0.6, Network 3 0.7, Network 4 0.9, Network 5 0.8</td>
</tr>
<tr>
<td>Load</td>
<td>Network 1 0.6, Network 2 0.4, Network 3 0.6, Network 4 0.7, Network 5 0.2</td>
</tr>
<tr>
<td>Remaining Battery</td>
<td>Network 1 0.5, Network 2 0.4, Network 3 0.3, Network 4 0.3, Network 5 0.3</td>
</tr>
<tr>
<td>Type of Application</td>
<td>Network 1 0.2, Network 2 0.9, Network 3 0.6, Network 4 0.6, Network 5 0.7</td>
</tr>
<tr>
<td>Preferred Network</td>
<td>Network 1 0.5, Network 2 0.6, Network 3 0.7, Network 4 0.6, Network 5 0.8</td>
</tr>
<tr>
<td>QoS Requirements</td>
<td>Network 1 0.3, Network 2 0.4, Network 3 0.4, Network 4 0.7, Network 5 0.6</td>
</tr>
</tbody>
</table>
During periodic scan, the Handover Initiation phase identified five Wi-Fi AP networks that has good QoS. The Handover Initiation phase trigger handover request to the Information Gathering phase. The handover metrics are collected and membership values of the attributes calculated for five networks.

6.5.1 Attribute Weights

Attribute weights are calculated based on user preference and application requirements. Table 6.3 shows the weights assigned to various attributes used in the experimentation.

<table>
<thead>
<tr>
<th>Handover Parameters</th>
<th>Attribute Weights</th>
<th>Handover Parameters</th>
<th>Attribute Weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>RSSI</td>
<td>0.154</td>
<td>Remaining Battery</td>
<td>0.083</td>
</tr>
<tr>
<td>LQI</td>
<td>0.105</td>
<td>Type of Application</td>
<td>0.095</td>
</tr>
<tr>
<td>Security</td>
<td>0.168</td>
<td>Preferred Network</td>
<td>0.102</td>
</tr>
<tr>
<td>Mobile Velocity</td>
<td>0.126</td>
<td>QoS Requirements</td>
<td>0.075</td>
</tr>
<tr>
<td>Load</td>
<td>0.092</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6.5.2 Grey Relational Co-Efficient

The grey relational co-efficient decides the rank of the network and it is calculated from the normal matrix (membership matrix) and weighted matrix (membership*weight). Table 6.4 depicts the results achieved.
### Table 6.4  Grey Relation Co-Efficient

<table>
<thead>
<tr>
<th>Handover Parameters</th>
<th>Grey Relation Co-Efficient ($\gamma(x_o(k),x_i(k))$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Network 1</td>
</tr>
<tr>
<td>RSSI</td>
<td>1.0</td>
</tr>
<tr>
<td>LQI</td>
<td>0.33</td>
</tr>
<tr>
<td>Security</td>
<td>0.37</td>
</tr>
<tr>
<td>Mobile Velocity</td>
<td>0.43</td>
</tr>
<tr>
<td>Load</td>
<td>0.59</td>
</tr>
<tr>
<td>Remaining Battery</td>
<td>0.50</td>
</tr>
<tr>
<td>Type of Application</td>
<td>0.37</td>
</tr>
<tr>
<td>Preferred Network</td>
<td>0.50</td>
</tr>
<tr>
<td>QoS Requirements</td>
<td>0.37</td>
</tr>
</tbody>
</table>

Network ranking is calculated based on the grey relational co-efficient.

![Diagram of network ranking](image)

**Figure 6.5  GRA-Network Ranking**
Figure 6.5 shows the ranking of available networks. It is clear that Network 1 (Wi-Fi 1) is the most suitable network for handover among all available networks in this current scenario.

6.6 RESULT ANALYSIS

6.6.1 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/network policy and in some cases, policy based handover is also possible. 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. Seven Wi-Fi networks have been found during the scan. The intelligent decision engine ranks the Wi-Fi AP-1 with highest ranking and sends probe request. AP accepts the probe request if it is not overloaded and does the further authentication/association process. If AP is overloaded, then it denies the probe request. In such cases, MT has to send probe request to the second highest ranked network. The maximum try for connection is set up to three to reduce the handover delay and handover processing in mobile assisted mode. But in network assisted mode, the AP sends the list of AP that has minimal load. The MT can choose any network from the received list from AP based on the preferences and rank.

6.6.2 Cooperative Decision Making

Wi-Fi AP (AP-hotspot) has been simulated in Ubuntu environment. The maximum try allowed for client to offload Wi-Fi has been set as three to reduce the handover delay. Table 6.5 shows the time taken for
handover of mobile associated mode and network assisted mode of cooperative decision making in a distributed environment.

### Table 6.5  Time elapsed for handover in mobile associated mode

<table>
<thead>
<tr>
<th>S. No</th>
<th>Connection Attempts</th>
<th>Time Elapsed (ms) in for mobile associated mode</th>
<th>Time Elapsed (ms) in for network assisted mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1.0846</td>
<td>0.8652</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>1.8554</td>
<td>0.9638</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>1.9252</td>
<td>1.0241</td>
</tr>
</tbody>
</table>

Figure 6.6  Time elapsed for handover in mobile associated and network assisted mode

Figure 6.6 details time elapsed for handover in both mobile associated and network assisted mode under the simulation scenario. It is observed that the handover delay increases as the number of handover requests
increase in both modes. But Compared to the mobile associated mode, network assisted mode requires minimum time to get connected. It is also found that network assisted mode performs better than mobile associated mode in terms of decision making and handover delay, but it requires periodic load advertisement.

6.6.3 Latency and Packet Loss

![Packet loss and latency analysis of our proposed algorithm](image)

**Figure 6.7** Packet loss and latency analysis of our proposed algorithm

Figure 6.7 shows the packet loss analysis and latency of our proposed algorithm. It is observed that the mobile terminal experiences minimum latency and packet loss. The average round trip time of Wi-Fi is relatively smaller than cellular network. On an average, our proposed algorithm has packet loss percentage of 0.4% during handover.
6.6.4 Envy-Free Fair Division

Wi-Fi AP allocates fixed bandwidth to the clients. In many cases, mobile terminal may not require the allocated level of bandwidth or may require more bandwidth. This causes bandwidth wastage and reduces spectrum efficiency. Hence, this aspect is mapped to fair division problem for efficient bandwidth allocation as per the requirement. Table 6.6 and 6.7 show the bandwidth allocation without and with envy free fair division auto choose sperner.

**Table 6.6 Bandwidth allocation without using envy free fair division-auto choose sperner**

<table>
<thead>
<tr>
<th>Users</th>
<th>Bandwidth Requirement</th>
<th>Bandwidth allocation using Auto Choose Sperner</th>
</tr>
</thead>
<tbody>
<tr>
<td>User 1</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>User 2</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>User 3</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>User 4</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>User 5</td>
<td>50</td>
<td>10</td>
</tr>
</tbody>
</table>

**Table 6.7 Bandwidth allocation using envy free fair division-auto choose sperner**

<table>
<thead>
<tr>
<th>Users</th>
<th>Bandwidth Requirement</th>
<th>Bandwidth allocation using Auto Choose Sperner</th>
</tr>
</thead>
<tbody>
<tr>
<td>User 1</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>User 2</td>
<td>20</td>
<td>12</td>
</tr>
</tbody>
</table>
User 3  
User 4  
User 5

The total bandwidth available is assumed to be 100. From the Table 6.6, it is observed that bandwidth will be allotted to the users as per their demands on first come first serve basis. Hence, there is a possibility of providing very poor QoS to the users connected in the later stage. The proposed algorithm overcome this drawback. From Table 6.7, it is observed that the proposed algorithm achieves fairness in allocation of bandwidth as per the actual needs to provide the necessary QoS to almost all connected end users as per their actual requirements truly based on their traffic class.

6.6.5 Proxy for Reducing Connection Block-outs

Hotspot shield VPN is used for reducing the connection block outs. The proxy is forced to use same IP for entire session and it is observed that it can maintain the connection alive in most of the applications. The supported applications are web surfing, multimedia applications, and online transaction applications. Applications that completely rely on the IP have very few block-outs during handover. Based on the QoS requirements and their type of application, application traffic is classified into five major categories based on Cisco recommendations: Best effort traffic including all noncritical traffic and HTTP web browsing; Interactive applications include interactive applications like Telnet, Oracle Thin-Clients, and Yahoo Instant Messenger. Bulk traffic includes Database syncs, network-based backups, video content distribution, and large FTP file transfers. Transactional applications include TCP and FTP session based applications.
Figure 6.8  Comparison of connection block outs with and without proxy

The Connection block-outs out of every 10 attempts are shown in Figure 6.8. It also illustrates the result obtained for the five different types of applications in demand.

6.6.6  Shortage of AP- Limitation of offloading

The possibility of offloading dependents on the number of available AP. The details of available cellular and Wi-Fi AP network details in surrounding places of our campus has been taken for the deployment of the proposed solution. These details are collected using an Open Signal Android application and depicted in Table 6.8.
Table 6.8 Availability of ap and connection acceptance rates

<table>
<thead>
<tr>
<th>Source of data</th>
<th>Number of Cells</th>
<th>Number of Wi-Fi AP</th>
<th>Number of Open AP</th>
<th>Connection acceptance on Open AP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coimbatore Junction</td>
<td>43</td>
<td>45</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>Tiruppur Junction</td>
<td>27</td>
<td>23</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Erode Junction</td>
<td>34</td>
<td>31</td>
<td>14</td>
<td>6</td>
</tr>
</tbody>
</table>

It is observed from the Table 6.8 that number of available open AP are highly limited and even the connection acceptance rate on the open AP are very minimal. This reduces the possibility of offloading. Hence, the collaboration between Wi-Fi operators and cellular operators is needed to increase the probability of offloading. A cellular operator makes a tie-up with the Wi-Fi operator to increase the possibility of offloading and their cellular site and Wi-Fi AP are called as a group.

A mobile terminal registered with that cellular operator receives authentication credentials and it can roam around their group with same authentication credentials. Authentication credentials of mobile terminal are encrypted using AES and sent over the open medium. The AP can decrypt the content only if it knows the shared secret key. The gateway collects the uplink/downlink usage data and then sends it to the operator’s service network. The service provider uses this information for billing and accounting system. The usage details of each mobile terminal at each gateway are encrypted using shared secret key and forwarded to billing and accounting server. AES with salting is used for secure transmission of billing and accounting information. Here, Salting process reduces the chances of encryption key guessing attacks.
Figure 6.9  Comparison of offloading possibility with proposed approach.

Figure 6.9 shows the offloading possibility in ordinary approach and collaborative approach. It is found that offloading possibility increases as the collaboration between operator increases.

6.7  CONCLUSION

Wireless heterogeneous networks are the future of mobile internet systems that provide large capacity and coverage. The integration of small cells and macro cells enables minimal latency, better coverage, cell edge coverage and provides faster upload/download times, and better indoor/outdoor coverage. The proposed approach enables the mobile terminal to choose the optimal network using fuzzy logic system and multiple attribute decision making. The participation of Wi-Fi access point and mobile terminal in decision making reduces the handover delay to an acceptable minimum level in a simulated environment. The cooperative decision making helps to improve the QoS to the users, load balancing, load advertisement, and handover delay. The collaboration of the cellular operators and Wi-Fi
operators to increase the possibility of offloading to 93% and the usage of proxies reduce the connection block-outs by 70%. The future work is to design and build a tight and robust connectivity engine for service continuity during handover using proxies.