CHAPTER 6

APPLICATION OF GAME THEORY FOR PEER SELECTION FOR COLLABORATION ACTIVITY

In the previous chapters, the peers were selected and ranked on the basis of their peer configurations, or otherwise termed as static attributes. This chapter looks at Phase two of the selection process. Here the peers which are short-listed in phase one are once again ranked based on their available resources. As explained in Chapter 4, the peer resources are used for a variety of activities and do not remain static. Hence, Phase two selection is essential to ensure that resources are available for the collaboration activity and task execution does not fail due to unavailability of resources.

This chapter presents the novel approach of using Game Theory to compare and rank peers in the Phase two of the decision making process. This is done through the dominant properties of the peers. The previous methods rank peers by considering the full set of peers with the requisite resources. This chapter proposes the use of game theory to compare peers in pairs and rank peers from the short-list of peers having available resources.

6.1 INTRODUCTION TO GAME THEORY

Game theory is a method that can be used for independent and interdependent decision making (Anthony 2003). In many practical problems, it is required to take decision in a situation where there are two or more opposite parties with conflicting interest and the action of one depends upon the action of the opponent (Morris 1994). The outcome of the situation is
controlled by the decisions of all the parties involved. Such a situation is termed as a competitive situation.

The term ‘game’ refers to the general situation of conflict and competition in which two or more competitors or participants are involved in decision-making activities in expectation of certain outcomes over a period of time (Paul et al 2003). The competitors are referred as players. The strategy for a player for winning the game is the list of all possible actions that he will take for every outcome that might arise.

Generally, two types of strategies are employed by players in a game (Anthony 2003). In pure strategy, the decision rule is always used by the player to select the particular strategy. In this type, each player knows all the strategies in advance and selects only one particular strategy regardless of the other player’s strategy and the objective of the players is to maximize gains or minimize losses. The strategy in which the courses of action that are to be selected on a particular occasion with some fixed probability is called mixed strategy. There is a probabilistic situation and objective of the players is to maximize expected gains or to minimize expected losses.

The proposed system for peer selection uses pure strategy approach termed as zero-sum game (Melissa et al 2008). The game involves comparing two peers at a time. If the sum of gains to one peer is exactly equal to the sum of losses to another peer, then the game is said to be zero-sum game. The peers involved in collaboration may have a competitive situation. For instance, the peer which is need of resources may adapt an incentive scheme for collaboration. In this scenario, the peers who want to share their resources may have competition among themselves. The requesting peer may have conflict in selecting the peers. The concept of game theory can be applied to resolve the competition and to select the right peer for collaboration. Thus the
proposed system introduces the concept of applying game theory for multi attribute ranking in P2P networks.

6.2 PEER SELECTION FOR COLLABORATION USING GAME THEORY

Peers having higher probability in resource sharing need to be selected for the collaborative work. As explained in the earlier sections, peers selected in Phase I have to once again go through the selection process of Phase II. In Phase II, the selection process is based on the dynamic attributes which denote the current availability of resources with the peers. The available resources have to be matched again with the requirements of collaboration activity. Game theory model selects the optimal peer and during decision making process it verifies the interdependence of the peer with others.

Two -person game theory technique is adopted between two-peers for deciding the right peer (Theodore et al 2001). The requirements of the peers for P2P collaboration are collected dynamically as independent attributes. The attributes have to be compared with the existing availability of the resources. The process of reselection of peer begins by the pair-wise comparison of attribute values of the peers. From the outcome of first pair-wise comparison, dominant peer is identified. This dominant peer is then compared with the third peer and the process continues till all the peers are ranked. Thus the number of peers for the execution of the application can be restricted based on the collaborative work.

The following block diagram explains the steps involved to decide dominant peer.
6.3 WORKING RULE

A matrix is formed by arranging the peers along row wise and their attribute values along column wise. Let Peer\(_1\), Peer\(_2\), ..., Peer\(_m\) be ‘m’ possible peers for resource sharing. Let \(W_1\), \(W_2\), ..., \(W_n\) be the weighting factor for considering the importance given to the attributes.

For instance, the sample attributes considered are Disk Free Space (DFree), Receiving Data Rate (Rx) and Transmitting Data Rate (Tx). The attribute values of the peer given in Table 6.1 and are represented as a matrix ‘X’.

![Figure 6.1 Block diagram of Multi attribute ranking using Game Theory](image-url)
Table 6.1 Sample input attribute values of the peers

<table>
<thead>
<tr>
<th>Attributes</th>
<th>DFree</th>
<th>Rx</th>
<th>Tx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peer 1</td>
<td>8</td>
<td>419</td>
<td>402</td>
</tr>
<tr>
<td>Peer 2</td>
<td>35</td>
<td>221</td>
<td>161</td>
</tr>
<tr>
<td>Peer 3</td>
<td>14</td>
<td>3602</td>
<td>2421</td>
</tr>
</tbody>
</table>

\[
X = \begin{pmatrix}
8 & 419 & 402 \\
35 & 221 & 161 \\
14 & 3602 & 2421
\end{pmatrix}
\]

6.4 NORMALIZATION

The normalization technique is applied to standardize the attribute values equivalently even though the representation of the attribute differs. This is done by dividing the corresponding entity with sum of squares of entities in the corresponding location. For example, the representation unit of ‘DFree’, ‘Rx’ and ‘Tx’ are represented as real values. Further process is carried out with the normalized values. The normalized matrix \( R = [r_{ij}] \) is generated using the Equation 4.9.

The normalized values lie between 0 and 1. The generated normalized matrix for the considered input attributes is given as:

\[
R = [r_{ij}] = \begin{pmatrix}
0.2076 & 0.115331 & 0.163453 \\
0.908249 & 0.060831 & 0.065462 \\
0.3633 & 0.991463 & 0.984377
\end{pmatrix}
\]
6.5 **ASSIGNMENT OF WEIGHTING FACTOR**

The relative importance of each attribute in the peer is indicated by weight $W$. Weighting factor is assigned to each of the attributes based on the application/user requirements. The weight values of all the attributes are defined in the range 0 to 1 using the Equation 4.8. The sum of the weights assigned must be 1.

The sample weight values assigned for DFree, Rx and Tx are 0.2, 0.5, and 0.3 respectively whose sum is 1. The product of weighting factor with the normalized values results in a weighted matrix. The generated weighted matrix $V$ for the considered normalized attributes is given as: $V = R^*W = [r_{ij}] * w_j$ using the Equation 4.10.

The generated weighted matrix $V$ for the considered normalized attributes is given as:

$$
V = R^*W = [r_{ij}] * w_j = \begin{pmatrix} 0.04152 & 0.057666 & 0.049036 \\ 0.18165 & 0.030415 & 0.019639 \\ 0.07266 & 0.495731 & 0.295313 \end{pmatrix}
$$

6.6 **PAYOFF MATRIX GENERATION**

Pair wise comparison of the weighted attributed is carried out as shown in Equation 6.1.

$$
Payoff (i, j)_{i=1...\text{Num of Attribute}} = (V_{1,i} - V_{2,j})_{i=1...\text{Num of Attribute}}
$$

where

$$
V_{1,i} \rightarrow i^{th} \text{ attribute of peer1, for } i = 1 \text{ to number of attributes}
$$
$V_{2,i} \rightarrow j^{th}$ attribute of peer2 for $j = 1$ to number of attributes

The Payoff matrix obtained by the pair-wise comparison is given below:

$$
\begin{array}{c|cccc}
\text{Peer}_2 \\
\hline
\text{Peer}_1 & P_{2,1} & P_{2,2} & P_{2,3} & \ldots & P_{2,n} \\
\hline
P_{1,1} & \left( \begin{array}{cc}
V_{1,1} - V_{2,1} & V_{1,1} - V_{2,2} \\
V_{1,2} - V_{2,1} & V_{1,2} - V_{2,2} \\
\vdots & \vdots \\
V_{1,n} - V_{2,1} & V_{1,n} - V_{2,2}
\end{array} \right) & V_{1,1} - V_{2,3} & \ldots & V_{1,1} - V_{2,n} \\
\hline
P_{1,2} & V_{1,2} - V_{2,1} & V_{1,2} - V_{2,2} & \ldots & V_{1,2} - V_{2,n} \\
\vdots & \vdots & \ddots & \vdots \\
\hline
P_{1,n} & V_{1,n} - V_{2,1} & V_{1,n} - V_{2,2} & \ldots & V_{1,n} - V_{2,n}
\end{array}
$$

In the generated payoff matrix, the first row shows the dominance of values of payoff as $V_{1,1}$ of Peer$_1$ over $V_{2,1}, V_{2,2}, \ldots V_{2,n}$ of Peer$_2$. The second row shows the dominance of values of payoff as $V_{1,2}$ of Peer$_1$ over $V_{1,1}, V_{1,2}, \ldots V_{2,n}$ of Peer$_2$ and so on. Similarly each column indicates the dominance of payoff values of Peer$_2$ over Peer$_1$. Hence the pair-wise comparison between the attributes has been carried out. The first two rows of the weighted matrix $V$ is selected for the payoff matrix computation. The payoff matrix is generated using the Equation 6.1.

The first two rows which representing Peer$_1$ and Peer$_2$ of the obtained weighted matrix are considered as the inputs for payoff matrix generation is given as:

$$
\begin{array}{c|ccc}
\text{Peer}_1 & 0.04152 & 0.057666 & 0.049036 \\
\text{Peer}_2 & 0.18165 & 0.030415 & 0.019639
\end{array}
$$

The pair-wise comparison of the attributes has been carried out and the payoff matrix is generated using the Equation 6.4 for the considered example.
The resulting payoff matrix of the game for the considered example is given as:

\[
\begin{bmatrix}
0.041520 - 0.18165 & 0.041520 - 0.030415 & 0.041520 - 0.019639 \\
0.057666 - 0.18165 & 0.057666 - 0.030415 & 0.057666 - 0.019639 \\
0.049036 - 0.18165 & 0.049036 - 0.030415 & 0.049036 - 0.019639
\end{bmatrix}
\]

6.7 DECIDING DOMINANT PEER (WINNER PEER)

According to pure strategy of game theory, the objective of the game is to know how the peers must select their strategy so that they may optimize their payoff. Such a decision making criterion is referred to as the minimax-maximin principle. Such principle in pure strategies game always leads to the best possible selection of a strategy for both peers.

For example, minimum value of Peer\(_1\) in each row represents the least gain to Peer\(_1\). These are written in the matrix by row minima. Then the strategy that gives largest gain is selected among the row minimum values. The choice of Peer\(_1\) is called the maximin principle, and the corresponding gain is called the maximin value of the game. Similarly, for Peer\(_2\), who is assumed, to be the looser the maximum value in each column represents the maximum loss to it. If he chooses that particular strategy these are written in the payoff matrix by column maxima. Then, the strategy that gives minimum loss among the column maximum values is selected. The choice of Peer\(_2\) is called the minimax principle, and the corresponding loss is the minimax value of the game.

If the maximin value equals the minimax value, then the game is said to have a saddle (equilibrium) point and the corresponding strategies are
called optimal strategies. The payoff amount in the saddle-point position is also called value of the game “$g$”.

The maximin and minimax values and the saddle point for Peer$_1$ and Peer$_2$ are evaluated in the following way.

\[
\begin{array}{ccc}
-0.14013 & 0.011104 & 0.021881 \\
\underline{-0.12398} & 0.027250 & 0.038027 \\
-0.13261 & 0.018620 & 0.029397 \\
\end{array}
\]

The maximin value of the game and minimax value of the game is represented as $\underline{g}$ and $\overline{g}$ respectively. The value of the game, generally satisfies the equation (maximin value $\leq$ $g$ $\leq$ minimax value). If $\underline{g}$ and $\overline{g}$ are equal to 0, then the game is fair game. If $\underline{g}$ and $\overline{g}$ are equal, then the game is said to be strictly determinable and the corresponding strategy is called optimal strategy. If saddle point value is negative, Peer$_2$ dominates Peer$_1$, or otherwise Peer$_1$ dominates Peer$_2$. The strategy is said to be pure strategy.

\subsection*{6.8 RANKING}

The dominant peer is selected from iteration by ranking the peers based on payoff matrix. The arrangement of the dominant peer makes the ranking optimistic. There is no restriction for using different iteration methods in ranking the selected peers. By using those methods the time taken for completing the process may vary.
6.9 PERFORMANCE ANALYSIS

The system has been implemented and tested using 640 peers. It is assumed that every peer advertises its available resources that could be dedicated for collaborative tasks. The requesting peer gives its specification for requirement and ranking of peers is done on the basis of the attributes that would satisfy the requirements. This system was implemented in Java and tested with the dataset generated by PlanetLab from Computer Networking Research laboratory. The system was tested by varying the number of attributes to be 3, 5 and 7. The performance results are shown in Figure 6.2 and 6.3. Figure 6.2 shows the results for count of peers from 1 to 50 while 6.3 shows the results for peers upto 640.

![Figure 6.2 Performance analysis of the system for 10-50 peers.](image-url)
Figure 6.3 Performance analysis of the system for 50-640 peers.

The graphs show that initially the time taken for decision making is independent of the attribute selection. However time increases proportionally to the number of attributes. The process of decision making is fast when the number of peers is less irrespective of the number of attribute and is shown using the graph in Figure 6.3.

6.10 CONCLUSION

The proposed approach considers multiple heterogeneous, independent attributes for ranking peers for collaborative applications. The relative importance of the attributes is decided based on the P2P application, while game theory provides the mathematical technique for decision making and ranking the peers for collaborative activity. Game theory helps in optimal decision taking into consideration the collaborative application resource making and matching them with the resources available with the peers. It can be seen that this method is suitable for dynamic environments like P2P network as the comparison is made pair-wise.