THE ANALYTIC HIERARCHY PROCESS TECHNIQUE IN DETERMINING PROCUREMENT OF A LOCAL AREA NETWORK OPERATING SYSTEM

Author:
Laura A. Murphy, Blue Cross & Blue Shield of Michigan
Co-Authors:
Pedro P. Sanchez, Eastern Michigan University
Rao Tummala, Eastern Michigan Universtiry

ABSTRACT

The novel approach of Analytic Hierarchy Process (AHP) is the structuring of any complex problem into different hierarchy levels. In this paper, an attempt is made to apply this approach to the evaluation process of several different Local Area Network Operating System Software Packages. An individual was selected along with a set of attributes such as data integrity, confidentiality, and compatibility. The pairwise comparisons of these attributes at one level, the attributes given their capabilities within different architectures and the software packages given their architecture restrictions were obtained. These comparisons indicate the strengths with which one element dominates another. This scaling formulation can be translated into a largest eigenvalue problem which results in a normalized and unique vector of weights for the elements of each level of hierarchy. A single normalized composite vector of weights corresponding to each software package then was found using the AHP technique. Using the composition vector of weights, the decision maker can determine the most effective and versatile Local Area Network Operating System software package for the particular implementation of a local area network.

INTRODUCTION

The analytic hierarchy process (AHP) modeling technique is a recent one among the approaches used to determine the relative importance of a set of attributes or activities or criteria. The novel idea in applying this technique is the structuring of any complex, multiperson, multicriterion and multiperiod problem by means of hierarchies. The elements or attributes in each level of the hierarchy with respect to an element of the next higher level hierarchy are compared pairwise by assigning weights. These weights reflect the strengths with which one element dominates the other and will be formed as a square matrix. It can be shown that the scaling of weights in this fashion and by a pairwise comparison matrix will be translated into a largest eigenvalue problem which results in a normalized and unique vector of weights for the attributes in each level of the hierarchies. These weights will be combined to obtain a single composite vector of weights for the entire hierarchy. This vector measures the relative importance priority of all attributes at the lowest level that enables the accomplishment of the highest objective of the hierarchy [2,3].

The AHP technique was applied successfully to several business, economic and societal problems [1,2,3]. In this paper, an attempt will be made to apply it to the determination of the most feasible operating system for a particular implementation of a Local area network. For the sake of confidentiality, the name of the individual judge and the software packages which were evaluated are not exposed.

THE ANALYTIC HIERARCHY PROCESS

The AHP is based on a trade off concept that will be accomplished by structuring the problem and assigning weights in the form of a series of pairwise comparison matrices as explained earlier. The approach constitutes three phases, namely structuring of the problem, assessment of weights (in the form of pairwise comparison matrices), and the analysis.

The structuring problem involves the decomposition of any complex problem into a series of hierarchies, where each level of a hierarchy consists of a few manageable elements or attributes and every one of these elements, in turn, are decomposed into another set of elements corresponding to the next level of hierarchy. Structuring any problem hierarchically in this fashion is an efficient way of dealing with complexity and identifying important attributes to achieve the overall objective of the problem. The AHP allows for the dependence-independence relations among attributes by decomposing them into different levels of hierarchies.

The second phase of AHP begins with the assessment of weights. This involves essentially the data collection and measurement. The judge will assign weights in a pairwise fashion with respect to the attributes of one level of hierarchy given the attribute of the next higher level of hierarchy. The scaling of weights used to compare attributes is called the nine-point scale and is discussed in detail in T. Saaty's book, The Analytic Hierarchy Process [3,4].

Following this scaling method, the judges will assign weights for each pair separately as to the degree to which one attribute of the pair dominates the other. Upon the completion of this process, the pairwise comparison matrices corresponding to each level of hierarchy will be obtained.

The third and the last phase of AHP is the analysis. As mentioned earlier the pairwise comparison matrices will be solved to obtain a normalized and unique vector of weights for each level of the hierarchy. Using these vectors a single composite vector of weights for the entire hierarchy will be obtained. these weights measure the relative importance of all entities at the lowest level that enable the accomplishment of the overall objective of the problem.

Suppose that a given hierarchy level has n attributes, $A_1, A_2, \ldots A_n$ with the vector of corresponding weights $w = (w_1, w_2, \ldots w_n)$. We wish to determine w in order to find the relative importance of $A_1, A_2, \ldots A_n$. If the judge assigns weights by comparing each pair A_i with A_j of these attributes as to the degree with which A_i dominates A_j as w_i/w_j and form the pairwise comparison matrix as:

	A_1	A_2	...	A_j	...	A_n
A_1	w_1/w_1	w_1/w_2		w_1/w_j		w_1/w_n
.						
A_i	w_i/w_1	w_i/w_2		w_i/w_j		w_i/w_n
.						
A_n	w_n/w_1	w_n/w_2		w_n/w_j		w_n/w_n

then the vector of weights $w = (w_1, w_2, \ldots w_n)$ can be found by solving a corresponding largest eigenvalue problem as

$$Aw = nw$$

Using this equation the vector of unique and normalized weights will be found for each level of hierarchy. Since the suggestive levels of hierarchies are related, a single composite vector of unique and normalized weights for the entire hierarchy will be determined by using the vectors of weights of the successive hierarchies (3). This composite vector will then be used to find the relative priority of all entities at the lowest level that enables the accomplishment of the highest objective of the hierarchy.

APPLICATION OF AHP TO THE PURCHASE OF A LOCAL AREA NETWORK OPERATING SYSTEM

The picture of distributed data processing has changed with the advent of network of personal computers. A network is a computer system that uses data communication equipment to connect two or more computers and their resources.

Of particular interest in today's business world are Local Area Networks (LANs), which are designed to share data and resources among several individual small computers, or workstations. The relatively high cost of quality disks and printers makes sharing these resources attractive.

The purchase decision of a LAN has recently changed. Package deals including hardware and software were the norm, however, buying network hardware independently from software offers the most flexibility.

The most critical element in any network is the LAN Operating System (OS). This operating system is the interface between the network's hardware, each workstation and the application software. In addition, it is the governing ruler of the network's behavior and performance. Operating system software is becoming increasingly flexible and is no longer limited to one architecture. However, hardware restrictions should still be considered, as many software packages are limited in the number of architectures supported.

Let use assume that Company A is interested in installing a Local Area Network. By applying the AHP technique, we wish to find a single composite normalized vector of weights for the LAN Operating Systems reviewed so that the LAN Operating System with the highest weight, or most effective options, will be purchased by Company A.

The structuring phase to achieve the above objective constitutes the problem into three levels of hierarchy such that the first level corresponds to 8 attributes. These attributes were chosen because of their relevance to a local area network. Each attribute is listed below with an explanation of its effect on the LAN:

1. **Dedicated Server (DS)**

   It is important to know if the operating system requires a device to be dedicated exclusively to running the network, thereby lending itself to be a centrally controlled environment. In this example, it is determined that for cost-effectiveness, the chosen software should not require a dedicated server.

2. Electronic Mail (EM)

The operating system can provide for users to exchange messages with other network users. This can be accomplished through a menu driven system or just a set of commands for the user to follow. Some offer the application as a separate package at additional cost.

3. User Interface (UI)

User interface relates directly to the Application Level of the OSI model. It should:

- o Provide user friendly network interface.
- o Provide for embedded commands from network applications.
- o Provide help and directory facilities.

4. Data Integrity (DI)

Data Integrity relates to the Session Layer of the OSI and is achieved if the network operating system:

- o Provides for file protection.
- o Performs file and record locking.
- o Provides error recovery facilities.

5. Network Confidentiality (NC)

The network should allow passwords to be stored in encrypted form. These passwords can be accessible by the administrator and allow files to be controlled by user passwords. This is also accomplished in the Session Layer of the OSI.

6. Supports NetBIOS (SN)

The network operating system will support IBM's Network Basic Input/Output System, the interface with the network hardware.

7. IBM PC DOS Applications (DA)

The network operating system will run IBM PC DOS Applications without modifications.

8. Bridge (BR)

A link or bridge to other LANs running different LAN Operating Systems is possible.

The second level relates the each software attribute to the different types of architecture and how each performs under different hardware restrictions. The hardware limitations being compared include the basic PC LAN Boards available. The three LAN Boards are IBM compatible and can be described using the topographical information.

1. Star (ST)
The star topology use either centralized or distributed control. The central node generally routes message traffic to outer nodes. Data transfer using this method is fairly efficient when data is moving from the center node, but can be heavy when data is transferred from an outer node to another outer node.

2. Ring (RN)

The ring topology has nodes which act as repeaters. Messages are passed from one node to another. Tokens are usually used to give permission to a particular node for use of the channel. Note that if any node fails, the network fails.

3. Bus (BS)

The Bus topology shares a single physical channel. Each message is sent to all nodes and the node must be able to recognize its address in the message. No messages are repeated as in a Ring topology and the failure of one node does not cause the network to fail.

The third level corresponds to the LAN Operating Systems being considered for purchase, namely SA, SB, SC and SD. These 3 levels of hierarchy are described in Figure 1.

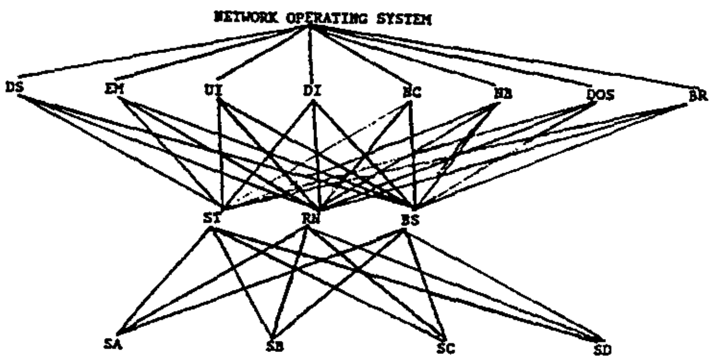

FIGURE 1: Local Area Network Hierarchical Structure

The assessment of weights by an individual in the data services unit will be as follows. First consideration is given to all possible pairs of attributes included in the first level hierarchy. For each of these pairs, weights are assigned following the nine-point scale as to the degree to which one attribute is more or less important than the other in order to determine the correct software to purchase. These weights will form a pairwise comparison matrix as follows:

	DS	EM	UI	DI	NC	SN	DA	BR
DS	1	DS vs. EM	DS vs. UI	DS vs. DI	DS vs. NC	DS vs. SN	DS vs. DA	DS vs. BR
EM		1	EM vs. UI	EM vs. DI	EM vs. NC	EM vs. SN	EM vs. DA	EM vs. BR
UI			1	UI vs. DI	UI vs. NC	UI vs. SN	UI vs. DA	UI vs. BR
DI				1	DI vs. NC	DI vs. SN	DI vs. DA	DI vs. BR
NC					1	NC vs. SN	NC vs. DA	NC vs. BR
SN						1	SN vs. DA	SN vs. BR
DA							1	DA vs. BR
BR								1

The entries in the lower triangular matrix are the reciprocal values of the corresponding entries of the upper triangular matrix. In this example, the determination of weights are assessed on their importance to a particular implementation of the LAN. For example, is it more important to have an electronic mail system or an effective user interface. Once this is completed, weights are assigned by comparing relevant pairs of the second level hierarchy given each attribute of the second level heirarchy given each attribute of the first level heirarchy. For example, given DS, they should assign weights for ST vs. RN, ST vs. BS, and RN vs. BS to obtain the corresponding pairwise comparison matrix as:

	ST	RN	BS
ST	1	ST vs. RN	ST vs. BS
RN		1	RN vs. BS
BS			1

In a similar fashion, the pairwise comparison matrices given EM, UI, DI, NC, SN, DA, and BR of the first level hierarchy attributes will be obtained. In each of these cases, the 3 architecture structures are compared relative to each separate attribute. The comparisons were completed to determine whether the structures either handle situations in a similar fashion, are more effective, or do not handle the particular situation at all. Again, the nine-point table described above was used. The analysis is done by calculating the eigenvalue of each matrix.

Also included are pairwise comparison matrices given the hardware restrictions, ST, RN, and BS of the second level hierarchy attributes will be obtained. In each of these cases, the 4 operating system software packages SA, SB, SC, SD are compared relative to each speparate hardware restrictions. The comparisons were completed to determine whether the packages can handle the topology restrictions, are more effective or do not handle the particular situation at all. The nine-point scale was used again to conclude this comparison. The eigenvalue of each matrix was then calculated.

A computer program to solve the corresponding largest eigenvalue problems in order to find the vector of weights is written. The same program also provides the way of combining the weights to obtain the normalized weights to SA, SB, SC, and SD. Using these weights, the most effective operating system will be determined. In particular, the operating system with the highest weight will be purchased.

The computer program used for this analysis is the software package ATAHP, designed at Eastern Michigan University, and written in fully transportable FORTRAN. The input and output to the software is provided by the main driver subroutine [4].

RESULTS and CONCLUSIONS

Using the algorithm, the weights of the first level hierarchy attributes and the weights of the second level hierarchy attributes given the attributes of the first hierarchy level and the weights of the third level hierarchy attributes given the attributes of the second hierarchy level are found as described in Figure 2.

LEVEL 1	
DS	0.1864
EM	0.0575
UI	0.2015
DI	0.125
NC	0.0547
SN	0.1784
DA	0.1784
BR	0.0177

LEVEL 2	DS	EM	UI	DI	NC	NB	DOS	BR
ST	0.091	0.081	0.1	0.571	0.818	0.333	0.333	0.6
RN	0.091	0.639	0.3	0.285	0.091	0.333	0.333	0.3
BS	0.818	0.279	0.6	0.142	0.091	0.333	0.333	0.1

LEVEL 3	ST	RN	BS
SA	0.0833	0.45	0.45
SB	0.0833	0.05	0.05
SC	0.0833	0.45	0.05
SD	0.75	0.05	0.45

FIGURE 2: Eigenvalue Matrices Calculated From The Comparison Matrices

From the above figures, the weights w_{SA}, w_{SB}, w_{SC}, and w_{SD} for each software package is computed by multiplying the third level matrix by the second level matrix and then multiplying the sum of these to the first level matrix.

Your final decision matrix is displayed below:

DECISION CHART	
SA	0.3442
SB	0.0595
SC	0.1711
SD	0.4242

As explained earlier these weights are normalized and reflect the relative priority of the four operating system software packages. Consequently, the operating system with the largest weight should be purchased. Therefore, SD should be purchased by Company A.

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