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Internet Network Design for Quality of Service Guarantee Using Data Envelopment Analysis (DEA)

E. Alipour Chavari[1], M. Rostamy-Malkhalifeh[*2]

[(1,2,3)] Department of Mathematics, Science and Research Branch, Islamic Azad University, Tehran, Iran

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Abstract
Videoconference, using a mechanism is needed to support the quality of service of the application programs. Different models have been presented to guarantee the quality of service. Among these, the differentiated services can be mentioned which was presented by IETF. In the architecture of the differentiated services, no admission control mechanism is considered. To guarantee the quality of service, the differentiated services network should support the admission control mechanism. In order to have the best result of the admission control mechanism, the parameters of the network should be considered to decrease the rate of loss and delay as well as the increase of the network utilization. Therefore, due to the spontaneous evaluation of the efficiency of the different inputs and finding the best set of inputs which produce the best outputs, the Data Envelopment Analysis (DEA) is used. Data Envelopment Analysis is one of the scientific approaches which computes the efficiency using the strong mathematical basis. In this paper, first the parameter based admission control mechanism is added to the edge routers of the differentiated services network and implemented by NS-2 simulator. Then, the best set of inputs is using the DEA.

Keywords: Quality of Service, Admission Control, Differentiated Services Network, DEA Technique.

*. Corresponding author: Email: mohsen_rostamy@yahoo.com

1. Introduction

Real time multimedia applications are increasingly becoming an important part of Internet traffic. The new Internet applications widely require the quality of service. Different networks have been presented to guarantee the quality of service which the differentiated service is the most popular that includes several classes of services. Expedited forwarding (EF) class intended to offer low loss, low delay, low jitter, assured bandwidth such as VOIP and videoconferencing [3]. Assured forwarding (AF) designed to ensure that packets are forwarded with a high probability of delivery, as long as the aggregate traffic in a forwarding class does not exceed the subscribed information rate [4].

In order to make the quality of service guarantee, the differentiated services network should support the admission control mechanism. The process of deciding to accept or reject a new request is called admission control. The process of the admission control guarantees that there are sufficient resources in the network for each new input flow. The main role of the admission control in the guarantee of the quality of service is to control the rate of the traffic injected to the network so that prevent from the congestion of the network and provide the desirable quality.

Data Envelopment Analysis (DEA) is a scientific method which computes the efficiency by using the basis of the mathematics. Data envelopment analysis is a nonparametric technique to evaluate the relative efficiency of a set of the decision making units with the several inputs and outputs. The methods of the data envelopment analysis determine not only the relative efficiency rate but also the weak points of the networks in the different indices. One advantage of the DEA is to determine the optimal weights by the model for each DMU in order to have the highest efficiency, whereas these weights had been expressed by the manager in the past. In other words, the manager had played the main role in determining the efficiency of a unit.

In this paper, by the used method in the reference article [2], the parameter based admission control mechanism is added to the edge of the differentiated services network. Then, by changing the related inputs which include buffer size, the number of input sources, and the link capacity, the outputs including loss, delay and, utilization are obtained by using the simulation method with NS-2 simulator. In the studied differentiated services network, the noted network is considered as DMU, and studied the outputs by defining the different inputs of the network, and regarding the DEA technique, it is tried that the best group of the inputs which would cause the highest utilization and the quality of service guarantee is selected. Then, due to some undesirable outputs, some models are presented for the undesirable output.

The rest of this paper is organized as follows: section 2 presents the admission control and its criteria. Section 3 presents the data envelopment analysis while section 4 introduces the proposed scheme. The network efficiency evaluation and the results are presented in section 5. Finally, section 6 presents the conclusion.

2. Admission Control

Admission control is a set of actions to check whether a service request is to be admitted or rejected. The admission control scheme should have at least two main components: traffic descriptor and admission criteria [9]. The traffic descriptor is a set of parameters which identifies the worst case of the source behavior. One traffic descriptor is a set of token bucket parameters which is composed of the rate of filling buckets (r) and the bucket size of (b). Admission criteria are rules by which accept or reject an admission control scheme. If the new flow is accepted without affecting the quality of service of the existing flows, the source node will start sending the traffic. If accepting the new flow effects on the quality of service of the existing flows in the network, that flow will be rejected [9].

2-1. Admission Control Criteria

Admission criteria are the rules by which an admission control scheme accepts or rejects a request. Different admission control criteria have been proposed. In this paper, the equivalent capacity was used. The equivalent capacity C(ε) is an estimation of the arrival rate of a class of traffic such that the stationary arrival rate of the traffic exceeds C(ε) with a probability of ε. An admission control decision is made based on C(ε), the peak rate of the new flow P and the bandwidth allocated to the class C. A new request is admitted according to the following relationship:

$$C(\varepsilon)+P\leq C \tag{1}$$

There are two kinds of the equivalent capacity criteria. The [8] assumes the aggregate arrival rate models by a normal distribution with mean μ and variance σ^2. C(ε) is given by:

$$C(\mu,\sigma^2,\varepsilon)=\mu+\sigma\sqrt{2\ln\frac{1}{\varepsilon}+\ln(\frac{1}{2\pi})} \tag{2}$$

The mean μ and variance σ^2 of the aggregate arrival are either derived from the token bucket parameters or estimated from measurements. This model is appropriate for estimating the equivalent capacity of many numbers of the similar flows.

In [9], Floyd proposed another criterion. Given the peak rate of N sources, the equivalent capacity estimated by:

$$C(\mu,\{P_i\}_{1\leq i\leq n},\varepsilon)=\mu+\sqrt{\frac{\ln(1/\varepsilon)\sum_{i=1}^{n}(P_i)^2}{2}} \tag{3}$$

The average arrival rate μ is estimated using one of the measurement techniques. The peak rate is either provided by the source or derived from the token bucket parameters using:

$$P=r+\frac{b}{U} \tag{4}$$

Where r is the token bucket rate, b is the bucket size and U is the measurement interval. The new request is admitted when the sum of the new request and equivalent capacity is less than total bandwidth.

3. Data Envelopment Analysis (DEA)

3-1. The principles governing the DEA:

Suppose DMU_J J= (1, ..., n) is available with the input vector $x_j=(x_{1j}\ldots,x_{1m})$ and the output vector $y_j=(y_{1j},\ldots y_{sj})$, and all the inputs and outputs are non-negative and have at least one positive component. These inputs and outputs need to apply in the following principles [1].

1) Inputs and outputs must be congruent.

2) The output should be dependent on these inputs.

3) Data synchronization.

3-2. Input Oriented CCR Model:

$$\begin{aligned} &\min \theta \\ &St: \\ &\sum_{j=1}^{n}\lambda_j x_j+s^-=\theta x_o \\ &\sum_{j=1}^{n}\lambda_j y_j-s^+=y_o \\ &s^-\geq 0 \qquad s^+\geq 0 \end{aligned} \tag{5}$$

Definition: The Optimal value of θ^* is called the technical efficient of the decision-making unit and the amount of (1- θ^*) is called the technical inefficient. On this basis, θ^* $(1-x)_0$ is the amount of the loss input of the under evaluated unit.

3-3. SBM model

$$\min \rho = \frac{1-\frac{1}{m}\sum_{i=1}^{m}\frac{s_i^-}{x_{ip}}}{1+\frac{1}{s}\sum_{r=1}^{s}\frac{s_r^+}{y_{rp}}}$$

$$\begin{aligned} & st: \\ & \sum_{j=1}^{n}\lambda_j x_{ij} + s_i^- = x_{ip} \\ & i=1,\dots,m \\ & \sum_{j=1}^{n}\lambda_j y_{rj} - s_r^+ = y_{rp} \\ & r=1,\dots,s \\ & \lambda_j \ge 0 \quad s_i \ge 0 \quad s_r \ge 0 \\ & j=1,\dots,n \quad i=1,\dots,m \quad r=1,\dots,s \end{aligned} \tag{6}$$

4. Proposed Algorithm

4-1. The proposed algorithm for the admission control mechanism

In this paper, the parameter based admission control is used which was implemented in article reference [2]. In the parameter based admission control, the client determines its traffic's properties. In the proposed schemes, the mean μ and variance σ^2 related to the arrival traffic should be defined by the client. The equivalent capacity criterion was used to control the bandwidth, and the multiplexed effective bandwidth was estimated according to (2). ε determines the amount of loss threshold.

In the proposed algorithm, it is assumed that through provisioning of the network and traffic engineering, C_{total} bandwidth is available edge to edge for the real time traffic. It is also assumed whenever a source wants to send traffic; it will inform its request to the ingress node through a reservation protocol. A similar assumption is considered for the time of ending one service. That is at the time of ending one service, the source considered to ingress node informs the end of the service. Therefore, PBAC process knows the number of active sources in each input node.

When a new request arrives at the edge of the network, it should be considered whether accepting the new flow damages the quality of services of the existed flows or not. Knowing the number of active sources and the peak rate of the new traffic and assuming that the new source is sending traffic with peak rate, the required bandwidth for accepting the new request is computed according to equation (7).

$$C_{est} = \sum_{i=1}^{n} P_i + P_{new} \tag{7}$$

Where P_i is the highest rate of sending the active sources and n is the number of active sources which is available in the network. Having the allocated bandwidth C_{total} and obtaining C_{est}, the admission control criterion is:

$$\begin{aligned} & if \quad C_{est} \le C_{total} \quad admit \\ & if \quad C_{est} > C_{total} \quad reject \end{aligned} \tag{8}$$

This scheme guarantees the quality of service even if all the sources send traffic with the peak rate. However, since no traffic measurement is taken into consideration, the utilization is low and the sources' blocking rate is high.

4-2. The proposed algorithm for the DEA

4-2-1. DEA models for undesirable data:

The data are called undesirable when increasing the outputs or decreasing the inputs is not good for the system. Three methods have been proposed to solve this problem:

First method: in this method, the undesirable inputs become the desirable outputs and the undesired outputs become the desirable inputs.

$$\begin{aligned} & \max \varphi \\ & st: \\ & \sum_{j=1}^{n}\lambda_j x_{ij} \le x_{ip} \qquad i \in D_x \end{aligned}$$

$$\sum_{j=1}^{n}\lambda_j x_{ij} \geq \varphi x_{ip} \qquad i \in UD_x$$
$$\sum_{j=1}^{n}\lambda_j y_{rj} \geq \varphi y_{rp} \qquad r \in D_y \tag{9}$$
$$\sum_{j=1}^{n}\lambda_j y_{rj} \leq y_{rp} \qquad r \in UD_y$$
$$\lambda \geq 0$$

Disadvantages of this method:

1- The output should be changed in the output position, but the input had changed in the second constraint.

2- The output should be increased, but the output had decreased in the fourth constraint.

Second method: in this method, the input vector does not change, and the output vector is classified into the desirable outputs and undesirable outputs.

$$\max \varphi$$
$$st:$$
$$\sum_{j=1}^{n}\lambda_j x_{ij} \leq x_{ip} \qquad i = 1,\ldots,m \tag{10}$$
$$\sum_{j=1}^{n}\lambda_j y_{rj} \geq \varphi y_{rp} \qquad r \in D_y$$
$$\sum_{j=1}^{n}\lambda_j y_{rj} \leq \frac{1}{\varphi} y_{rp} \qquad r \in UD_y$$
$$\lambda \geq 0$$

The problem of this method is that it is non-linear way.

Third method: in this method, first the undesirable output become symmetry and then is added with a positive value in order to respect the non-negative condition of the outputs.

$$\forall j \quad y_{rj} \to -y_{rj} \to y_{rj} + K > 0 \tag{11}$$

The problem of this method is that it is true in models which are consistent to the transfer.

In this paper, some models were proposed for the undesirable outputs.

5. Simulated Network Topology

NS-2 simulator was used to add the admission control algorithm in the differentiated services network [3]. The dumbbell topology was used which is shown in figure 1. This network was considered as DMU and different DMUs would be made by determining different inputs.

In this paper, the simulation of two classes of network traffic has been considered: the differentiated service class or EF class and best-effort class or BE class. 120 sources in the desirable topology are considered which generate traffic in the network. These sources generate two types of traffic. EF traffic is the VoIP traffic and BE traffic is the best effort traffic which produce a high percentage of Internet traffic.

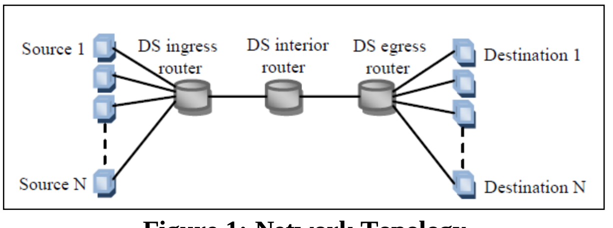

Figure 1: Network Topology

5 -1. Definition of the inputs and outputs

First input: among the sources, the sources which dealt with producing the EF traffic were considered as the first input. The value of these inputs is shown in table 1. The number of BE sources also would be changed which were equal to difference the number of the EF sources from all sources. For these two traffic classes, the separate queues were used.

Second input: the size of EF traffic queue was considered as the second input which their values are shown in Table 1. The size of BE traffic queue was considered 20. For modeling the VoIP traffic, the exponential ON/OFF model with a peak rate of 64 Kbps and mean duration for the ON and OFF periods 1.004 sec and 1.587 sec was used respectively. BE traffic was generated with a rate of 50 Kbps. Duration of the traffic of a source was considered a random number with the normal distribution and the mean of 10 seconds. The capacity of the output link was 3.1 Mbps which this capacity was divided between the EF and BE traffic.

The third input: the amount of the link capacity allocated to EF traffic was considered as the third input which is shown in table 1.

The desirable outputs were achieved by performing the simulations for each DMU with the duration of 1000 seconds.

First output: the rate of the packet loss related to EF traffic.

Second output: the delay rate of sending EF traffic packets from the source to destination.

Third output: the network utilization.

DMUs and the input and output values are presented in Table 1.

I_1= The number of input sources

I_2 = buffer size (packet)

I_3 =EF link capacity(Kbps)

O_1= utilization (%)

O_2 = loss(%)

O_3 = delay (ms)

Table 1: DMUs and the input and output values

DMU	I_1	I_2	I_3	O_1	O_2	O_3
DMU_1	90	3	600	83.46	5.37	13.94
DMU_2	70	3	600	84.62	4.28	13.52
DMU_3	50	3	600	85.73	3.89	13.60
DMU_4	30	3	600	85.02	4.19	13.94
DMU_5	90	4	500	85.85	6.19	15.37
DMU_6	70	4	500	87.50	5.28	14.68
DMU_7	50	4	500	82.32	3.35	14.35
DMU_8	30	4	500	84.36	5.65	15.25
DMU_9	50	3	500	85.49	6.97	14.00
DMU_{10}	70	3	500	80.47	6.75	13.93
DMU_{11}	30	5	500	84.88	5.42	15.82
DMU_{12}	50	5	500	84.67	2.85	14.46
DMU_{13}	70	5	500	86.05	3.87	15.24
DMU_{14}	30	4	700	79.85	0.12	13.55
DMU_{15}	30	3	700	78.00	2.45	13.40
DMU_{16}	50	3	700	78.50	2.09	12.97
DMU_{17}	70	3	700	76.91	2.22	13.07
DMU_{18}	70	4	700	78.70	0.10	13.27
DMU_{19}	90	3	700	76.72	2.54	13.27
DMU_{20}	90	4	700	78.66	0.08	13.35
DMU_{21}	90	5	600	88.16	1.35	14.75
DMU_{22}	70	5	600	55.42	0.63	14.23
DMU_{23}	30	5	600	88.54	1.05	14.83
DMU_{24}	50	5	600	88.72	0.39	13.96

DMU	I_1	I_2	I_3	O_1	O_2	O_3
DMU_{25}	70	2	600	77.56	12.35	13.00
DMU_{26}	30	3	500	82.39	7.70	14.52
DMU_{27}	90	3	500	82.89	9.30	14.46
DMU_{28}	90	5	500	87.11	6.31	16.48
DMU_{29}	50	4	700	80.07	0.13	13.06
DMU_{30}	90	4	600	86.54	2.12	14.60
DMU_{31}	70	4	600	87.21	1.31	14.19
DMU_{32}	30	4	600	87.82	1.62	14.58
DMU_{33}	50	4	600	88.07	1.10	13.79

Since the outputs of the loss packets and the delay are the undesirable outputs, the DEA models are presented for the undesirable outputs in this section.
In this section, several scenarios are considered to assess the efficiency of the presented DMUs. These scenarios are included:

First scenario: the model with ε
Second scenario: The SBM model
Third scenario: the revised model of Triantis based on Tanasoulis [10]

5-2. The first scenario: the model with ε

Model with ε is corrected for the undesirable outputs:

$$
\begin{aligned}
&\min \rho = 1 - \frac{1}{m}\sum_{i=1}^{m}\frac{s_i^-}{x_{ip}} \\
&st: \\
&\sum_{j=1}^{n}\lambda_j x_{ij} + s_i^- = x_{ip} \\
&i = 1,\dots,m \\
&\sum_{j=1}^{n}\lambda_j y_{rj} - s_r^+ = y_{rp} \\
&r = 1,\dots,s \\
&\lambda_j \ge 0 \quad s_i \ge 0 \quad s_r \ge 0 \\
&j = 1,\dots,n \quad i = 1,\dots,m \quad r = 1,\dots,s
\end{aligned}
\tag{12}
$$

The model of (12) represents the following results:
1– Efficiency and inefficiency of DMUs
2– the efficiency number
3– Reference Set
These results are shown in Table 2:

Table 2: These results of the model with ε

DMU	efficiency	$S(i_1)$	$S(i_2)$	$S(i_3)$	$S(o_1)$	$S(o_2)$	$S(o_3)$	Reference- sets
DMU_1	0.9490	34.0941	0	0	0	0	0.5343	3,9,25
DMU_2	0.9802	18.5291	0	0	0	0	0.0499	3,9,25
DMU_3	1	0	0	0	0	0	0	3
DMU_4	1	0	0	0	0	0	0	4
DMU_5	0.9811	19.6228	0	0	0	1.0095	0.9668	6
DMU_6	1	0	0	0	0	0	0	6
DMU_7	1	0	0	0	0	0	0	7
DMU_8	1	0	0	0	0	0	0	8
DMU_9	1	0	0	0	0	0	0	4
DMU_{10}	0.9412	18.8255	0	0	0	0.1892	0.7520	9
DMU_{11}	1	0	0	0	0	0	0	11
DMU_{12}	1	0	0	0	0	0	0	12
DMU_{13}	1	0	0	0	0	0	0	13
DMU_{14}	1	0	0	0	0	0	0	14
DMU_{15}	1	0	0	0	0	0	0	15
DMU_{16}	1	0	0	0	0	0	0	16

DMU	efficiency	S(i1)	S(i2)	S(i3)	S(o1)	S(o2)	S(o3)	Reference- sets
DMU_{17}	0.9698	19.3974	0	10.7204	0	0	0.4232	3,16
DMU_{18}	0.9928	5.2969	0	0	0	0	0	14,20,29
DMU_{19}	0.9488	37.9530	0	30.9417	0	0	0.7687	3,16
DMU_{20}	1	0	0	0	0	0	0	20
DMU_{21}	0.9576	35.6964	0	0	0	0	0.5394	12,24,33
DMU_{22}	0.9875	19.0971	0	0	0	0	0.2323	12,24,33
DMU_{23}	1	0	0	0	0	0	0	23
DMU_{24}	1	0	0	0	0	0	0	24
DMU_{25}	1	0	0	0	0	0	0	25
DMU_{26}	1	0	0	0	0	0	0	26
DMU_{27}	0.9695	38.7834	0	0	0	2.5419	0.8857	9
DMU_{28}	0.9955	19.9108	0.9955	0	0	1.0535	1.8654	6
DMU_{29}	1	0	0	0	0	0	0	29
DMU_{30}	0.9543	35.2505	0	0	0	0	0.9061	6,9,33
DMU_{31}	0.9842	19.0634	0	0	0	0	0.5041	6,9,33
DMU_{32}	1	0	0	0	0	0	0	32
DMU_{33}	1	0	0	0	0	0	0	33

As it can be considered, the DMUs of 1,2,5,10,17,18,19,21,22,27,28,30,31 are inefficient.

Now the inputs of the inefficient DMUs were changed in order to be efficient. Since the point of $\begin{pmatrix} x_p \\ y_p \end{pmatrix}$ is like $\begin{pmatrix} \theta^* x_p - s_i^- \\ y_p + s_r^+ \end{pmatrix}$, the new inputs are obtained from the relationship

$$x_p = \theta^* x_p - s_i^- \tag{13}$$

we run the program with this new inputs. Table 3 shows the results:

5-3. Second Scenario: The SBM model for the undesirable data.

Due to the particular form of inputs and outputs, the SBM model was used in the input position.

Table 3: The results of the revised model

DMU	efficiency	S(i1)	S(i2)	S(i3)	S(o1)	S(o2)	S(o3)	Reference-sets
DMU_1	0.9899	1.3517	0	0	0	0.2249	0.3853	*2,27*
DMU_2	1	0	0	0	0	0	0	2
DMU_5	1	0	0	0	0	0	0	5
DMU_{10}	1	0	0	0	0	0	0	10
DMU_{17}	1	0	0	0	0	0	0	17
DMU_{18}	1	0	0	0	0	0	0	18
DMU_{19}	0.9929	0	0	14.1899	0	0	0.5023	2,17,31
DMU_{21}	1	0	0	0	0	0	0	21
DMU_{22}	1	0	0	0	0	0	0	22
DMU_{27}	1	0	0	0	0	0	0	27
DMU_{28}	1	0	0	0	0	0	0	28
DMU_{30}	0.9983	0	0	0	0	0	0.3218	5,10,21,31
DMU_{31}	1	0	0	0	0	0	0	31

$$\min \rho = 1 - \frac{1}{m+k}\left(\sum_{i=1}^{m}\frac{s_i^-}{x_{ip}} + \sum_{i=1}^{m}\frac{s_i^-}{y_{ip}}\right)$$
$$st:$$
$$\sum_{j=1}^{n}\lambda_j x_{ij} + s_i^- = x_{ip} \qquad i \in D_x \tag{14}$$
$$\sum_{j=1}^{n}\lambda_j y_{rj} - s_r^+ = y_{rp} \qquad r \in D_y$$
$$\sum_{j=1}^{n}\lambda_j y_{rj} + s_r^+ = y_{rp} \qquad r \in UD_y$$
$$\lambda_j \geq 0 \quad s_i \geq 0 \quad s_r \geq 0$$
$$j = 1,\dots,n \quad i = 1,\dots,m \qquad r = 1,\dots,s$$

It should be noted that SBM Model considers all inefficiency in computing ρ, whereas CCR Model considers only the technical inefficiency.

Suppose that r is the output of the undesirable k-number.

$$\mu_r^* = \delta_r^* = 1 \tag{15}$$

The results of this model are shown in table 4.

Table 4: The results of the SBM model

DMU	efficiency	S(i1)	S(i2)	S(i3)	S(o1)	S(o2)	S(o3)
DMU_1	0.80	60.6108	0	12.2161	0	1.4222	0.2447
DMU_2	0.90	25.1381	0	7.2341	0	0.4697	0
DMU_3	1	0	0	0	0	0	0
DMU_4	1	0	0	0	0	0	0
DMU_5	0.87	33.6363	0	0	0	1.6227	0.9968
DMU_6	1	0	0	0	0	0	0
DMU_7	1	0	0	0	0	0	0
DMU_8	1	0	0	0	0	0	0
DMU_9	1	0	0	0	0	0	0
DMU_{10}	0.86	29.4788	0	0	0	1.5860	0.7123
DMU_{11}	1	0	0	0	0	0	0
DMU_{12}	1	0	0	0	0	0	0
DMU_{13}	1	0	0	0	0	0	0
DMU_{14}	1	0	0	0	0	0	0
DMU_{15}	1	0	0	0	0	0	0
DMU_{16}	1	0	0	0	0	0	0
DMU_{17}	0.89	35.4359	0	24.8064	0	0	0.0555
DMU_{18}	0.98	5.7946	0.0284	4.9772	0	0	0
DMU_{19}	0.83	48.2666	0	167.9784	0	0	1.1020
DMU_{20}	1	0	0	0	0	0	0
DMU_{21}	0.75	40.6707	0.0434	0	0	0.9679	08547
DMU_{22}	0.86	20.3593	0.0232	0	0	0.2442	0.3047
DMU_{23}	1	0	0	0	0	0	0
DMU_{24}	1	0	0	0	0	0	0
DMU_{25}	1	0	0	0	0	0	0
DMU_{26}	1	0	0	0	0	0	0
DMU_{27}	0.82	44.9093	0	0	0	3.2654	0.8651
DMU_{28}	0.85	22.7561	0.8621	0	0	1.3648	1.8303
DMU_{29}	1	0	0	0	0	0	0
DMU_{30}	0.79	41.9296	0	0	0	1.1314	0.9751
DMU_{31}	0.89	21.0846	0	0	0	0.2726	0.4928
DMU_{32}	1	0	0	0	0	0	0
DMU_{33}	1	0	0	0	0	0	0

As it can be considered, the DMUs of 1,2,5,10,17,18,19,21,22,27,28,30,31 are inefficient.
Now by changing in the inputs of the inefficient DMUs, we make them efficient.

$x_p^* = x_p - s_i^-$

5-4. Third Scenario: the revised model of Triantis based on Tanasoulis

Triantis classified the output vectors to desirable and undesirable classes. Then he gave them different weights in order to increase the desirable outputs and decrease the undesirable outputs.

$$
\begin{aligned}
&\max \sum_{r\in D_y} u_r\delta_r - \sum_{r\in UD_y} u_r\mu_r \\
&st: \\
&\sum_{j=1}^{n}\lambda_j x_{ij} \le x_{ip} \qquad i=1,\dots,m \\
&\sum_{j=1}^{n}\lambda_j y_{rj} = \delta_r y_{rp} \qquad r\in D_y \\
&\sum_{j=1}^{n}\lambda_j y_{rj} = \mu_r y_{rp} \qquad r\in UD_y \\
&\delta_r \ge 1 \\
&0 \le \mu_r \le 1 \\
&\lambda_j \ge 0 \\
&z^*
\end{aligned}
\tag{16}
$$

δ_r : the relative increase of the n desirable output

μ_r : the relative decrease of the n undesirable output

We have in the optimum solution: $\mu_r^* = \delta_r^* = 1$

In the Triantis' model, the weights are given by the manager of the network. Now, we obtain the best weights by the model (17). It should be noted that the input and output vectors are normalized first.

$$
\begin{aligned}
&\max W = \sum_{r\in D_y} u_r - \sum_{r\in UD_y} u_r - \sum_{i=1}^{m} v_i \\
&st: \\
&\sum_{r\in D_y} u_r y_{rp} + \sum_{r\in UD_y} u_r y_{rp} = z_p^* \\
&\left(\sum_{r\in D_y} u_r y_{rj} + \sum_{r\in UD_y} u_r y_{rj}\right) - \sum_{i=1}^{m} v_i x_{ip} \le 0 \\
&j=1,\dots,n \\
&v_i \ge 0 \qquad u_r \ge 0
\end{aligned}
\tag{17}
$$

z^* is the efficiency rate in the SBM model. The results are presented in table 5.

Table 5: The obtained weights of the Triantis' model

DMU	W	v (i_1)	v (i_2)	v (i_3)	u (o_1)	u (o_2)	u (o_3)
DMU_1	1.91	0.01	0.92	0.66	1.05	0.01	0.01
DMU_2	4.81	0.01	0.08	1.07	0.83	0.01	0.01
DMU_3	4.81	0.01	0.08	1.05	0.82	0.01	0.01
DMU_4	4.81	0.01	0.08	1.06	0.82	0.01	0.01
DMU_5	4.81	0.01	0.08	1.05	0.81	0.01	0.01
DMU_6	4.81	0.01	0.08	1.03	0.80	0.01	0.01
DMU_7	4.81	0.01	0.08	1.10	0.85	0.01	0.01
DMU_8	4.81	0.01	0.08	1.07	0.83	0.01	0.01
DMU_9	4.81	0.01	0.08	1.05	0.82	0.01	0.01
DMU_{10}	4.81	0.01	0.08	1.12	0.87	0.01	0.01
DMU_{11}	4.81	0.01	0.08	1.06	0.82	0.01	0.01
DMU_{12}	4.81	0.01	0.08	1.07	0.83	0.01	0.01
DMU_{13}	4.81	0.01	0.08	1.05	0.81	0.01	0.01
DMU_{14}	4.81	0.01	0.09	1.13	0.88	0.01	0.01
DMU_{15}	4.81	0.01	0.09	1.16	0.90	0.01	0.01
DMU_{16}	4.81	0.01	0.09	1.15	0.89	0.01	0.01
DMU_{17}	4.81	0.01	0.09	1.17	0.91	0.01	0.01
DMU_{18}	4.81	0.01	0.09	1.15	0.89	0.01	0.01
DMU_{19}	4.81	0.01	0.09	1.18	0.91	0.01	0.01
DMU_{20}	4.81	0.01	0.08	1.15	0.89	0.01	0.01
DMU_{21}	4.81	0.01	0.08	1.18	0.80	0.01	0.01
DMU_{22}	4.81	0.01	0.08	1.15	0.79	0.01	0.01
DMU_{23}	4.81	0.01	0.08	1.03	0.79	0.01	0.01
DMU_{24}	4.81	0.01	0.08	1.02	0.79	0.01	0.01
DMU_{25}	4.81	0.01	0.09	1.02	0.89	0.01	0.01
DMU_{26}	4.81	0.01	0.08	1.02	0.85	0.01	0.01
DMU_{27}	4.81	0.01	0.08	1.08	0.84	0.01	0.01
DMU_{28}	4.81	0.01	0.08	1.03	0.80	0.01	0.01
DMU_{29}	4.81	0.01	0.09	1.13	0.88	0.01	0.01
DMU_{30}	4.81	0.01	0.08	1.05	0.81	0.01	0.01
DMU_{31}	4.81	0.01	0.08	1.04	0.80	0.01	0.01
DMU_{32}	4.81	0.01	0.08	1.03	0.80	0.01	0.01
DMU_{33}	4.81	0.01	0.08	1.03	0.80	0.01	0.01

Regarding the obtained weights, it is considered that the third input (abundant capacity rate) is more important. The utilization is also more important among the outputs.

Now regarding the obtained weights from the model 17, the variables μ_r and σ_r of the model 16 are obtained.
The results are shown in table 6.

Table 6: The results of the variables μ_r and σ_r of the model 16

DMU	**W**	$\sigma(o_1)$	$\mu(o_2)$	$\boldsymbol{\mu(o_3)}$
DMU_1	1.08	1.04	0.93	1
DMU_2	0.82	1.01	0.89	1
DMU_3	0.80	1	1	1
DMU_4	0.80	1	1	1
DMU_5	0.81	1.02	0.85	0.95
DMU_6	0.78	1	1	1
DMU_7	0.83	1	1	1
DMU_8	0.81	1	1	1
DMU_9	0.80	1	1	1
DMU_{10}	0.90	1	1	1
DMU_{11}	0.80	1	1	1
DMU_{12}	0.81	1	1	1
DMU_{13}	0.79	1	1	1
DMU_{14}	0.86	1	1	1
DMU_{15}	0.88	1	1	1
DMU_{16}	0.87	1	1	1
DMU_{17}	0.91	1.03	1	1
DMU_{18}	0.88	1.01	1	1
DMU_{19}	0.93	1.05	1	0.99
DMU_{20}	0.87	1	1	1
DMU_{21}	0.81	1.04	1	1
DMU_{22}	0.78	1.01	1	1
DMU_{23}	0.77	1	1	1
DMU_{24}	0.77	1	1	1
DMU_{25}	0.87	1	1	1
DMU_{26}	0.83	1	1	1
DMU_{27}	0.85	1.03	0.75	0.97
DMU_{28}	0.79	1.01	0.84	0.89
DMU_{29}	0.86	1	1	1
DMU_{30}	0.83	1.04	1	0.98
DMU_{31}	0.84	1.02	1	0.98
DMU_{32}	0.78	1	1	1
DMU_{33}	0.78	1	1	1

6. Conclusion:

In order to make the quality of service guarantee, differentiated services network has to support admission control. A well designed admission control algorithm has an important effect on network performance. A conservative admission control will be less efficient but more likely to meet the quality of service requirements while a more efficient and aggressive admission control may be at the risk of not meeting the quality of service.

In this paper, the admission control mechanism was added to the edge routers of the network. Then, by changing the related inputs which included buffer size, the number of the input sources, and the EF link capacity, the outputs included loss, delay, and utilization were obtained by the simulation method with NS-2 simulator. In this paper, the differentiated services network was selected as the DMU and by giving different inputs, the different DMUs were made. Then, the efficiency of these inputs was investigated by DEA model.

The best group of the inputs was also selected by the DEA model. Then, the inputs which had not caused the increase of the quality of service were modified. The weights were also obtained for the inputs and outputs which showed their importance.

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