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Research Article

Evaluation of Active Queue Management Methods based on Integrated AHP, TOPSIS and Fuzzy TOPSIS

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Abstract: The Evaluation and selection of Active Queue Management (AQM) methods are a complicated and challenging task. Improper AQM method can cause up-mark and network malfunctioning. To achieve satisfactory performance, various evaluation criteria need to be considered. In order to find the limitations of how the criteria are determined, there is a need to find out how their procedures change according to the evaluation and benchmarking process of AQM. This article focuses on the evaluation and benchmarking of Active Queue Management methods using Multi-Criteria Decision-Making (MCDM) techniques. MCDM uses different techniques to figure out the best alternative from multi-criteria and multi alternative conditions. Analytic Hierarchy Process (AHP) is a multi-criteria decision-making technique that is used to assign weights to criteria. Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is used for ranking and selection of different alternatives by using distance measures. Whereas, FUZZY TOPSIS is used for criteria weightage and alternatives rating. MCDM calculation is performed on AQM methods and it is tried to discuss all these techniques. MCDM uses performance, overhead, and configuration criteria to evaluate and select the best AQM method that helps to determine solutions for future directions. The results show that Random Early Detection (RED) method got higher ranking score records as compared to other AQM methods.

Keywords: Active Queue Management; AHP; Fuzzy TOPSIS; Multi Criteria Decision Making; TOPSIS;

1. Introduction

Active Queue Management (AQM) is used for congestion control which was proposed by Floyd and Jacobson in 1990s. AQM [1] is a software that is installed in routers to manage the queue length. It holds buffers to accommodate packets and avoids congestion [2]. The Queue length is managed in routers to accommodate packets. In the drop tail queue, when the router capacity exceeds the available limit then the router starts dropping newly arriving packets [3]. Buffer has limited capacity, so when queue length increases then packets face a considerable delay which negatively affects the network performance. In network management, packet loss is a serious issue. So, when the traffic is congested then all incoming packets will be dropped due to router buffer overflow. This phenomenon leads to Global Synchronization. In Global Synchronization [4], the list of various AQM methods is:

- Random Early Detection [6]
- Robust Random Early Detection [7]

- Random Exponential Marking [8]

The basic purpose of this article is to evaluate and select best AQM method using MCDM techniques [9][10] [11] [12] [13].

1.1. MCDM Terms

Few important terms which are used in MCDM techniques are:

- Criteria
- Attributes
- Alternatives

1.1.1. Criteria

A criterion is a standard for each of its attributes and these attributes are evaluated against criteria. Criteria are needed to analyze an alternative which impact the selection of alternatives.

1.1.2. Attributes

Attribute is the quality or feature of an alternative. Attributes can be of qualitative or quantitative nature.

- Qualitative attribute represents specific properties of a person or an object which shows what that object or person looks like.
- In quantitative attribute, the attributes can be measured numerically such as maximum speed of a car, price of a house, etc.

1.1.3. Alternatives

The alternatives which are used in this dissertation are performance, overhead and configuration. The important key criteria terms which are used in performance are throughput, mean queue length, delay, dropping and loss. Overhead involves calculation, space and time whereas configuration involves parameter number.

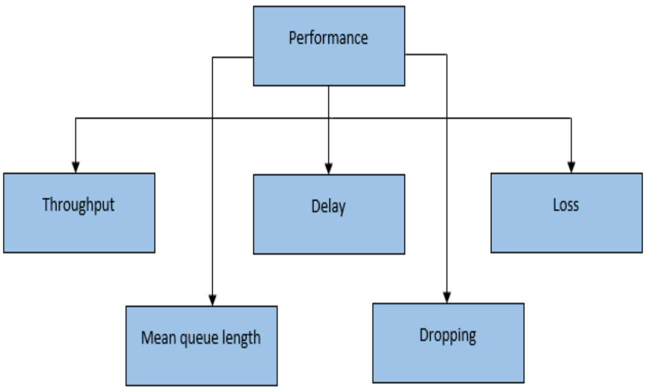

Figure 1. Criteria for performance

Performance:

In performance parameter, throughput, mean queue length, delay, dropping and loss are used for evaluation and selection of best AQM method. These criteria are sufficient for evaluation and benchmarking process of AQM [14-16]. The performance criteria are shown in Figure 1.

Throughput:

Throughput is defined as the number of packets that passes through the router queue buffer in a specified time period. T is proportional to performance, means performance increases when T increases. It is computed as:

T= $(\mathbf{1} - \boldsymbol{P_{ideal}}) * (\boldsymbol{\beta})$ **Equation** Error! No text of specified style in document..**1**

Where P_ideal represents the probability of ideal state and β is the value of packet departure.

Mean Queue Length:

MQL is defined as the number of packets that is accommodated in the router queue buffer in a specified period. It is computed as:

MQL= $\left(\frac{\mathbf{1}}{\mathbf{\#\ slots}}\right)\left(\sum_{\mathbf{i=1}}^{\mathbf{\#\ slots}} \mathbf{N(i)}\right)$ **Equation** Error! No text of specified style in document..**2**

Delay:

Delay is the waiting time for each packet in the router buffer. It is computed using MQL and throughput. It is inversely proportional to performance, means performance decreases when delay increases. Delay is computed as:

D=$\frac{\mathbf{mql}}{\mathbf{T}}$ **Equation** Error! No text of specified style in document..**3**

Dropping:

Dropping is the probability of dropping data packets. In case of heavy network congestion, dropping increases:

Loss:

Loss is the probability of dropping or losing data packets due to overflow in router buffer. The Packet loss is inversely proportional:

Loss= $(\mathbf{1}-\boldsymbol{\beta})$*PK **Equation** Error! No text of specified style in document..**4**

2. Problem Statement

In the traditional network management system like the drop tail queue, queue length was defined and it accepts only those packets which were in its predefined range and drops all other packets. Techniques like AHP, TOPSIS and FUZZY TOPSIS can be used to evaluate and select best AQM methods. Therefore, the objective of this research is to evaluate and analyze AQM methods using these MCDM techniques, so the AQM methods could be ranked as per their performance.

3. Methodology

The proposed methodology for evaluation and benchmarking of AQM methods is built in three phases: preliminary study, research study design and evaluation and selection. The methodology of AQM is presented in Figure 2.

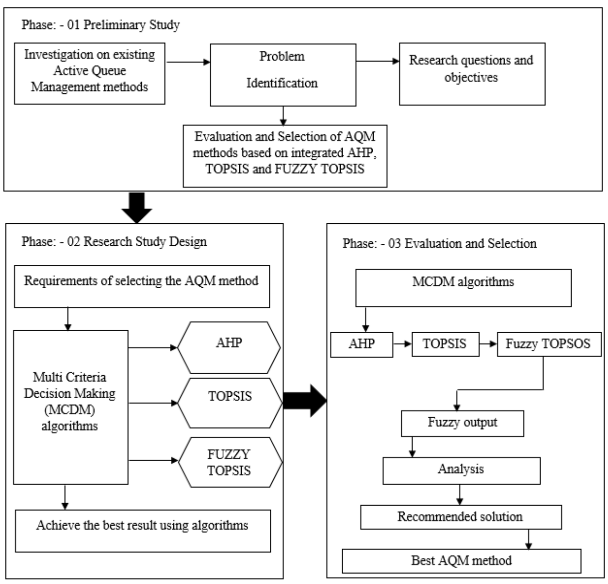

Figure 2. Methodology

3.1. Phase-1: Preliminary Study

Preliminary study is the first phase of developing any system or exploring any issue. It involves better quality research and evaluation results. This phase covers following steps:
- Investigation on existing AQM methods
- Problem identification
- Evaluation and selection of AQM methods
- Research objectives and questions

Problem Identification:

Problem identification is the base for developing a project or system. The identified problem is Evaluation and Selection of the AQM methods based on integrated AHP, TOPSIS and FUZZY TOPSIS.

Evaluation and selection of AQM methods:

In this problem, MCDM techniques such as AHP, TOPSIS and FUZZY TOPSIS are applied. AHP is used for criteria weightage. TOPSIS is used for alternatives ranking and FUZZY TOPSIS is used for alternate ratings. These approaches help to find the best AQM method

Research Objectives and Questions:

Research objective is a list of goals that needs to be accomplished. Research objectives check the project feasibility

3.2. Phase-2: Research Design

This phase includes the following sections:
1. Requirements of selecting the AQM methods
2. MCDM Algorithms
3. Evaluation and selection of AQM methods
4. Research objectives and questions

Requirements of selecting the AQM methods:

Problem identification is the base for developing a project or system. The identified problem is Evaluation and Selection of the AQM methods based on integrated AHP, TOPSIS and FUZZY TOPSIS.

MCDM Algorithms:

MCDM works on real life complex problems. It is applied in such areas there is a difficulty to make a decision. MCDM works on following components. Commonly used MCDM methods are:
- Analytic Hierarchy Process (AHP)
- Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)
- Fuzzy TOPSIS

The details of these methods are given in the next section.

3.3. Phase-3: Evaluation and Selection

In this phase, MCDM techniques such as AHP, TOPSIS and FUZZY TOPSIS are applied on AQM methods which help to make quick and efficient decision. The result of these techniques is a fuzzy output on which sensitive analysis is performed. A solution is proposed after the sensitive analysis which gives the best method for Active Queue Management. The Evaluation and Selection process of AQM is shown in Figure 3

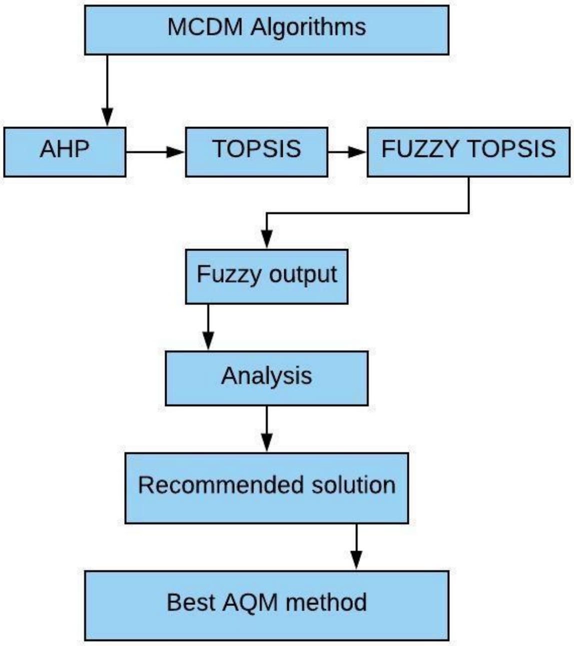

Figure 3. MCDM procedure

The detailed procedure of AHP, TOPSIS and fuzzy TOPSIS is described in the next sections.

4. Analytic Hierarchy Process

AHP is one of the MCDM techniques which aims at deriving ratio scales from pair wise comparison matrix. The step-by-step process of AHP is depicted in Figure 4.

AHP is one of the MCDM techniques which aims at deriving ratio scales from pair wise comparison matrix [12].

4.4.1. Working steps for AHP

This phase includes the following sections:

1. Making pair wise comparison
2. Making comparison matrix/reciprocal matrix
3. Normalized eigen vector
4. The eigen value
5. Consistency index (Ci)
6. Consistency ratio (Cr)
7. Result based on Cr value

Making pair wise comparison:

In pair wise comparison, an item or product along with its specification is compared with other having same specification. Such a comparison is a pair wise comparison.

Making comparison matrix/reciprocal matrix:

In this step, subjective judgement is done. A scale is defined for values {1, 3, 5, 7, and 9}

Normalized eigen vector:

Normalized vector can be obtained as taking the sum of each column and divide each element of the column by the sum of the same column. By this, relative weights are obtained, where the sum of each column must be 1

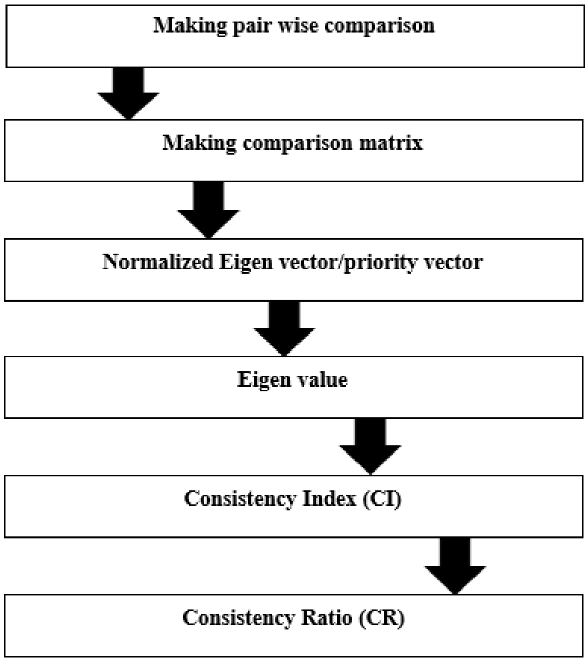

Figure 4. AHP technique

The eigen value:

The Eigen value is represented by λmax. It can be calculated by the sum of the column of comparison matrix and the sum of the product between each column of the priority vector.

Consistency index (Ci):

CI, named as Consistency Index can be obtained as

$$CI = \frac{\lambda max - n}{n-1}$$ **Equation** Error! No text of specified style in document..**5**

Consistency ratio (Cr):

CR is calculated using

$$CR = \frac{CI}{RI}$$ **Equation** Error! No text of specified style in document..**2**

RI is Random Consistency Index, whose values are:

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Result based on Cr value:

- If the value of CR<=10 then inconsistency is acceptable
- If CR>10, then there is a need to revise the subjective judgement

5. TOPSIS

TOPSIS is an MCDM technique that is used to rank alternatives.

5.1. Working steps for topsis

All the process of TOPSIS including each step is defined in the following subsections.

1) Construction of a Decision Matrix

The decision matrix (DM) is constructed using m alternatives and n criteria.

2) Normalization
Normalization is obtained as the square of the values in step 1 and then taking the sum of each column
3) Computation of the weight matrix
The weights are obtained from AHP algorithm.
4) Computation of Weighted Normalized
This decision matrix is obtained as multiplying the weights in step 3 by each column of the normalized decision matrix.
5) Calculation of PIS and NIS
PIS is Positive Ideal Solution and NIS is Negative Ideal Solution.
6) Determine the separation measures for each alternative
The separation measures define the distance that helps to compute closeness coefficient
7) Computation of RCC to the ideal solution
RCC is Relative Closeness Coefficient. Depending on RCC value, best alternative is selected. RCC is calculated using

Ci*= Si'/ (Si*+ Si')

which rank the alternatives depending on the shortest distance.

6. Fuzzy TOPSIS

It is an application of fuzzy set theory.

6.1 Working steps for fuzzy topsis

All the process of TOPSIS including each step is defined in the following subsections.
1) Selection of fuzzy rating scale for linguistic variables
In FUZZY TOPSIS, criteria and alternatives are in linguistic form so there is a need to define scale for rating.
2) Criteria weights and fuzzy ratings for alternatives
When a scale is defined, decision makers assign weights to criteria and define ratings for alternatives.
3) Computation of Fuzzy Aggregated ratings for alternatives
The Fuzzy aggregated rating is obtained by taking minimum, average and maximum values across each row.
4) Construction of Aggregated fuzzy decision matrix (AFDM)
The Aggregated Fuzzy Decision Matrix is formed in the form of matrix.
5) Normalization of AFDM
Linear scale Transformation (LST) is used for the normalization purpose. The normalized TFNs are within the interval of [0, 1]. In this step, cost and benefit criteria are calculated.
6)Weighted Normalized Fuzzy Decision Matrix (WNFDM)
The Weighted Normalized Fuzzy Decision Matrix is obtained in the form of matrix.
7) Determination of FPIS & FNIS
The Fuzzy Positive Ideal Solution (FPIS) is obtained as taking the maximum value which is the 3rd component. The Fuzzy Negative Ideal Solution (FNIS) is obtained as taking the minimum value.
8) Calculation of distances
Distance is calculated Euclidian distance formula.

$$d= \sqrt{(\mathbf{x_2}-\mathbf{x_1})^2+(\mathbf{y_2}-\mathbf{y_1})^2}$$

Equation Error! No text of specified style in document..**6**

9) Determination of Closeness Coefficients (CCi)
Alternatives closeness coefficients is obtained as

$$\mathbf{CC}_{\mathbf{i}=\frac{\mathbf{di^-}}{\mathbf{di^-+di^*}}}$$

Equation Error! No text of specified style in document..**7**

10) Ranking the alternatives
Alternatives are ranked as "alternative having CCi close to 1 shows that alternative is close to FPIS and away from FNIS".

7. Analytic hierarchy process for AQM

AHP is a MCDM technique developed by Prof. Thomas L. Saaty in 1970s. The basic purpose of this technique is to derive ratio scales from pair wise comparison matrix.

Selection of best AQM method is the problem here, and first, AHP is used to rank the AQM methods on the basis of various essential attributes.

Consider, decision makers are represented by

DM= {DM1, DM2, DM3, DM4, DM5}

Alternatives are performance, configuration and overhead.

7.1. Step 1: Making pair wise comparison

It is defined in terms of which item is better than other and how much you like or dislike the particular item.

Number of comparisons = $\frac{n(n-1)}{2}$

The scale for the comparison is set for the numbers {1, 3, 5, 7, and 9}

The first alternative is performance and their criteria are Throughput (T), Mean Queue Length (MQL), Delay, Dropping and Loss.

7.2. Step 2: Making comparison matrix / reciprocal matrix

In this step, Lower triangle will be formed by taking the inverse of the diagonal value of matrix. The diagonal element will be 1. Lower triangle will be formed by taking the inverse of the diagonal value of matrix. The comparison matrix is shown in **Error! Reference source not found.**.

7.3. Step 3: Normalized Eigen Vector

The Eigen vector is obtained as taking the sum of each column of the matrix and dividing each element of the column with the sum of the same column. The resultant sum must be 1. The Normalized Eigen vector is shown in **Error! Reference source not found.**.

	T	**MQL**	**Delay**	**Dropping**	**Loss**
T	1	$\frac{\left(9+9+9+9+9\right)}{5}=9$	$\frac{\left(9+7+7+7+9\right)}{5}=7.8$	$\frac{\left(9+7+7+\frac{1}{7}+7\right)}{5}=6.02$	$\frac{\left(9+\frac{1}{3}+9+\frac{1}{7}+5\right)}{5}=4.69$
MQL	$\frac{1}{9}$	1	$\frac{\left(9+9+\frac{1}{3}+9+\frac{1}{3}\right)}{5}=5.53$	$\frac{\left(\frac{1}{5}+9+5+3+9\right)}{5}=5.24$	$\frac{\left(9+9+9+9+\frac{1}{7}\right)}{5}=7.22$
Delay	0.12	0.18	1	$\frac{\left(9+7+9+9+9\right)}{5}=8.6$	$\frac{\left(9+\frac{1}{9}+7+5+9\right)}{5}=6.02$
Dropping	0.16	0.19	0.11	1	$\frac{\left(1+9+9+9+9\right)}{5}=7.4$
Loss	0.21	0.13	0.16	0.13	1

Table 1. Comparison matrix

	T	MQL	Delay	Dropping	Loss
T	0.625	0.857	0.534	0.286	0.178
MQL	0.068	0.095	0.378	0.249	0.274
Delay	0.075	0.017	0.068	0.409	0.228
Dropping	0.1	0.018	0.007	0.047	0.281
Loss	0.131	0.012	0.010	0.006	0.037
Sum	0.999	0.999	0.997	0.997	0.998

Table 2. Normalized Eigen vector

Normalization can be obtained by averaging across the row.

$$w= \frac{1}{5}\begin{bmatrix} 0.625+0.857+0.534+0.286+0.178 \\ 0.068+0.095+0.378+0.249+0.274 \\ 0.075+0.017+0.068+0.409+0.228 \\ 0.1+0.018+0.007+0.047+0.281 \\ 0.131+0.012+0.010+0.006+0.037 \end{bmatrix}$$

$$w= \frac{1}{5}\begin{bmatrix} 2.48 \\ 1.064 \\ 0.797 \\ 0.453 \\ 0.196 \end{bmatrix}$$

$$w=\begin{bmatrix} 0.496 \cong 49.6\% \\ 0.212 \cong 21.2\% \\ 0.159 \cong 15.9\% \\ 0.090 \cong 9\% \\ 0.039 \cong 3.9\% \end{bmatrix}$$

This is normalized principal Eigen vector which is also called priority vector.

7.4. Step 4: Eign Value

λ_{max} is Eigen value which is obtained as taking sum of the column of reciprocal matrix and sum of the product between each column of the priority vector.

λ_{max}=(1.6)(0.496)+(10.5)(0.212)+(14.6)(0.159)+(0.090)(20.99)+(0.039)(26.33)=0.793+2.226+2.321+1.889+1.026

λ_{max} = 8.255

7.5. Step 5: Consistency Index

Consistency is defined as the correctness of subjective judgement. How precise or accurate our measurement is? This scenario is resolved through Consistency Index (CI) using

$$CI = \frac{\lambda max - n}{n-1}$$

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$CI = \frac{8.225-5}{5-1} \Rightarrow = \frac{3.255}{4}$

CI=0.81375s

7.6. Step 6: Consistency Ratio

CR is calculated using **Error! Reference source not found.**. RI value can be selected

According to this ratio, if CR is less than or equal to 10% then inconsistency is acceptable. However, if CR is greater than 10%, then subjective judgement will be revised.

CR is computed, where CI=0.813 and RI=1.12

$CR = \frac{0.813}{1.12}$

CR=0.726<10 which is acceptable inconsistency.

All the above steps are repeated for second alternate, which is overhead

7.7. Step 1: Making pair wise comparison

The criteria for overhead are calculation, time, and space. Make a pair wise comparison for these criteria.

7.8. Step 2: Making comparison matrix

Reciprocal matrix is obtained from **Error! Reference source not found.**.

	Calculation	**Time**	**Space**
Calculation	1	$\frac{9+9+7+\frac{1}{7}+5}{5}$=6.028	$\frac{9+9+9+\frac{1}{8}+7}{5}$=6.866
Time	0.166	1	$\frac{7+7+7+\frac{1}{7}+7}{5}$=5.628
Space	0.145	0.177	1
Sum	1.31	7.205	13.494

Table 3. Comparison matrix

7.9 TOPSIS FOR AQM

TOPSIS is a Multi-Criteria Decision-Making technique developed by Yoon and Hwang in 1981s. The main purpose of this technique is to choose the alternative that has smallest geometric distance from PIS and largest distance from NIS. It is a Compensatory method which requires relative weights from AHP technique. Selection of best method is the problem here, and selection can be improved further using

TOPSIS. Consider the following; Decision makers are represented by DM= {DM1, DM2, DM3, DM4, DM5} The attributes for performance are throughput (T), Mean Queue length (MQL), Delay, Dropping, and Loss. Consider AQM methods; RED, SRED, PI, GRED: These methods will be evaluated against the following criteria. Throughput (T) and Mean Queue length (MQL) are the benefit criteria. Delay, dropping and loss are the cost criteria.

8. DISCUSSION

Queue mamagement was a problem in traditional system where queue limit was defined and it accepts only those packets which were in its range and rejects or drops all subsequent packets. Later on, AQM was introduced which minimizes unnecessary dropping of packets. In AQM, threshold value is used, which defines its range and accepts the incoming packets within its range and drops the remaining packets. There exists variety of AQM methods but selection of best AQM method was a critical task. To resolve this scenario, Multi-Criteria Decision Making techniques are used. These techniques involve AHP, TOPSIS, SMART, HAW, FUZZY TOPSIS, SAW, Fuzzy AHP etc. However AHP, TOPSIS and FUZZY TOPSIS are being used in this research for evaluation and selection purposes that provide more accurate results. The relationship between tecniques is shown in figure 5.

AHP is used to assign weights to criteria. In AHP, self-comparison for the criteria is done and after that weights for criteria are calculated and at the end inconsistency is checked. Criteria weight obtained from AHP is shown below and it is to be used in TOPSIS technique.

$$w=\begin{bmatrix} 0.496 \cong 49.6\% \\ 0.212 \cong 21.2\% \\ 0.159 \cong 15.9\% \\ 0.090 \cong 9\% \\ 0.039 \cong 3.9\% \end{bmatrix}$$

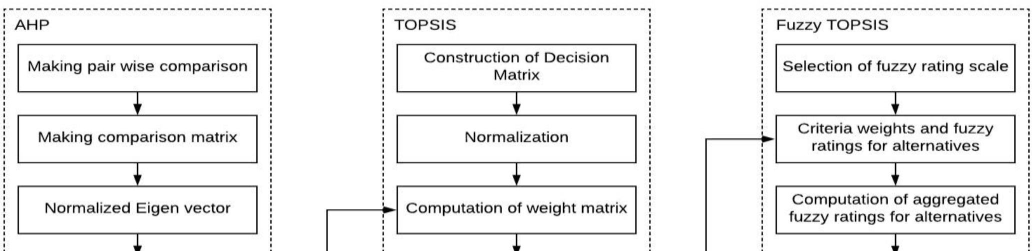
TOPSIS technique is used to rank alternatives. A list of AQM methods is selected by network designers, on which TOPSIS technique is applied. In TOPSIS, criteria weights obtained from AHP are used. The results after applying TOPSIS technique are shown in table 25. The results according to given criteria show that RED method got higher ranking score records as compared to other AQM methods.

FUZZY TOPSIS is advanced form of TOPSIS technique. It uses ranked list of alternatives obtained from TOPSIS technique. Some of the methods are obtained from ranked list of TOPSIS. RED and SRED are the most promising methods in TOPSIS. FUZZY TOPSIS technique is applied on these two selected methods which gives the following results.

$$RED = CC_1 = \frac{d1^-}{d1^- + d1^*} = \frac{18.022}{18.022+19.174} = \mathbf{0.4845}$$

$$SRED = CC_2 = \frac{d2^-}{d2^- + d2^*} = \frac{20.914}{20.914+22.968} = 0.4765$$

RED is the best method considering the given criteria. The remaining methods will be ranked in descending order. Table 2 presents the criteria weightage marked by decision makers. Not all AQM methods are efficient in all parameters. It also presents that RED gains higher throughput, medium MQL and low delay, dropping and loss which is quite good for best AQM method. Other methods were found to be lacking in throughput and MQL.



9. COMPARISON OF AQM METHODS

The resultant graph shows that RED method ranked high score. The clear picture of comparative methods is shown in figure 6.

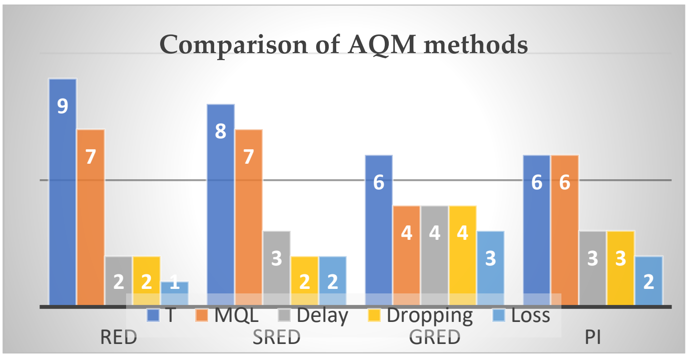


Figure 6. Comparison of AQM methods

9.1 PARAMETRIC REPRESENTATION

The parameters throughput, MQL, delay, dropping and loss are defined separately in the following tables. These tables clearly show that not all methods are good in all parameters.

1) Throughput

Throughput is the total number of packets that pass through the router queue buffer in a specified time slot. **Error! Reference source not found.** shows So, RED is a preferable method in terms of throughput.

Methods	Throughput	Preferable Method
RED	9	Red is preferable

SRED	8
GRED	6
PI	6

Table :04 Throughput

2) Mean Queue Length

MQL is the number of data packets that is accommodated in the router queue buffer in a specified period. **Error! Reference source not found.** shows that RED and SRED are preferable methods in terms of m ean queue length.

Methods	MQL	Preferable Method
RED	7	Red is preferable
SRED	7	SRED is preferable
GRED	4	
PI	6	

Table 05. MQL

3) Delay

It is the waiting time for each packet in the router queue buffer. So, method having minimum delay is preferable. Table shows RED method has minimum delay. So, it is a preferable method as compared to other AQM methods.

Methods	Delay	Preferable Method
RED	2	RED is preferable
SRED	3	
GRED	4	
PI	3	

Table 06. Delay

4) Dropping

Dropping is the probability of dropping data packets. The quantity of dropping should be low. Table shows that RED and SRED have minimum dropping values. So, both of these are preferable methods in terms of dropping.

Methods	Dropping	Preferable Method
RED	2	RED is preferable
SRED	2	SRED is preferable
GRED	4	
PI	3	

Table 07. Dropping

5) Loss

Loss is the probability of dropping or losing data packets due to overflow in router buffer. **Error! Reference source not found.** shows that RED has minimum rate of packet loss. So, RED is preferable method in terms of loss.

Methods	Loss	Preferable Method
RED	1	RED is preferable
SRED	2	
GRED	3	
PI	2	

Error! Reference source not found.. Loss

10. CONCLUSION

Active Queue Management is an active area of study and research for the researchers. AQM is most likely to be associated with buffer size and particularly about the networks having buffer size. This strategy gives a new way to assess AQM. This paper focuses on evaluation and selection of AQM using MCDM techniques such as AHP, TOPSIS and FUZZY TOPSIS. These techniques are used for selection of best AQM using less parameters because less parameters reduce the complexity. In MCDM algorithm, AHP gives the criteria weightage. Whereas in TOPSIS and FUZZY TOPSIS, relative closeness or closeness coefficient is used to rank best AQM for network congestion. Hence, it can be clearly said that fuzzy set theory along with AHP, TOPSIS and FUZZY TOPSIS is most effective for providing solution to the process of decision making in AQM. Study and mathematical computation show that RED gives better performance as compared to other AQM methods such as REM, SREM, PI, Drop tail queue, Random drop. The concept of Fuzzy set theory is used to handle uncertainties and to solve evaluation problems. Thus, AQM technique along with RED and FIFO is used for congestion control and performance analysis.

References

1. Abbasov, B., & Korukoglu, S., “Effective RED: An algorithm to improve RED’s performance by reducing packet loss rate,” Journal of Network and Computer Applications, 32(3), 703–709, 2009.
2. Abdel-jaber, H., Ababneh, J., Thabtah, F., Daoud, A. M., & Baklizi, M. “Performance Analysis of the Proposed Adaptive Gentle Random Early Detection Method under NonCongestion and Congestion Situations,” In International Conference on Digital Enterprise and Information Systems (pp. 592–603), 2011, Springer.
3. Abed, G. A., Ismail, M., Jumari, K., Abed, G. A., Ismail, M., Jumari, K., … Akyildiz, I. F. (2011). “Network Congestion Control: Managing Internet Traffic,” Research Journal of Information Technology, 3(4), pp-236.
4. Abualhaj, M. M., Abu-Shareha, A. A., & Al-Tahrawi, M. M., “FLRED: an efficient fuzzy logic based network congestion control method,” Neural Computing and Applications, 30(3), 925–935, 2018.
5. Khatari, Maimuna, A. A. Zaidan, B. B. Zaidan, O. S. Albahri, and M. A. Alsalem. “Multi-criteria evaluation and benchmarking for active queue management methods: Open issues, challenges and recommended pathway solutions.” International Journal of Information Technology & Decision Making 18, no. 04 (2019): 1187-1242.
6. Athuraliya, S., Li, V. H., Low, S. H., & Yin, Q., “REM: Active queue management.” In Teletraffic Science and Engineering (Vol. 4, pp. 817–828), 2001. Elsevier.
7. Aweya, J., Ouellette, M., & Montuno, D. Y. “A control theoretic approach to active queue management.” Computer Networks, 36(2–3), 203–235, 2001.
8. Baklizi, M., Abdel-Jaber, H., Abu-Shareha, A. A., Abualhaj, M. M., & Ramadass, S. “Fuzzy Logic Controller of Gentle Random Early Detection Based on Average Queue Length and Delay Rate.” International Journal of Fuzzy Systems, 16(1), 2014.
9. Tambe, Sagar B., and Suhas S. Gajre. “Novel Strategy for Fairness-Aware Congestion Control and Power Consumption Speed with Mobile Node in Wireless Sensor Networks.” In Smart Trends in Systems, Security and Sustainability, pp. 85-111. Springer, Singapore, 2018.

10. Brakmo, Lawrence S., Sean W. O'Malley, and Larry L. Peterson. "TCP Vegas: New techniques for congestion detection and avoidance." In Proceedings of the conference on Communications architectures, protocols and applications, pp. 24-35. 1994.
11. Brandauer, C., Iannaccone, G., Diot, C., Ziegler, T., Fdida, S., & May, M. "Comparison of tail drop and active queue management performance for bulk-data and web-like internet traffic." In Proceedings. Sixth IEEE Symposium on Computers and Communications (pp. 122–129). 2001. IEEE.
12. Casetti, C., Gerla, M., Mascolo, S., Sanadidi, M. Y., & Wang, R. "TCP Westwood: end-to-end congestion control for wired/wireless networks." Wireless Networks, 8(5), 467–479, 2002.
13. Xu, Changbiao, and Fengfeng Li. "A congestion control algorithm of fuzzy control in routers." In 2008 4th International Conference on Wireless Communications, Networking and Mobile Computing, pp. 1-4. IEEE, 2008.
14. Chen, C.-K., Liao, T.-L., & Yan, J.-J. "Active queue management controller design for TCP communication networks: variable structure control approach." Chaos, Solitons & Fractals, 40(1), 277–285, 2009.
15. Chen, X., & Heidemann, J. "Preferential treatment for short flows to reduce web latency." Computer Networks, 41(6), 779–794, 2003.
16. Chrysostomou, C., Pitsillides, A., Hadjipollas, G., Sekercioglu, A., & Polycarpou, M., "Fuzzy explicit marking for congestion control in differentiated services networks." In Proceedings of the Eighth IEEE Symposium on Computers and Communications. ISCC 2003 (pp. 312–319). 2003. IEEE.
17. Feng, W-C., Dilip D. Kandlur, Debanjan Saha, and Kang G. Shin. "A self-configuring RED gateway." In IEEE INFOCOM'99. Conference on Computer Communications. Proceedings. Eighteenth Annual Joint Conference of the IEEE Computer and Communications Societies. The Future is Now (Cat. No. 99CH36320), vol. 3, pp. 1320-1328. IEEE, 1999.
18. Feng, W., Kandlur, D., Saha, D., & Shin, K. "BLUE: A new class of active queue management algorithms." Technical Report CSE-TR-387-99, University of Michigan, 1999.
19. Feng, W., Shin, K. G., Kandlur, D. D., & Saha, D. "The BLUE active queue management algorithms." IEEE/ACM Transactions on Networking (ToN), 10(4), 513–528, 2002.
20. Figueira, J., Greco, S., & Ehrgott, M. "Multiple criteria decision analysis: state of the art surveys" (Vol. 78), 2005. Springer Science & Business Media.
21. Floyd, S., Gummadi, R., & Shenker, S. "Adaptive RED: An algorithm for increasing the robustness of RED's active queue management." Technical report, ICSI, 2001.
22. Floyd, S., & Jacobson, V. "Random early detection gateways for congestion avoidance." IEEE/ACM Transactions on Networking, (4), 397–413, 1993.
23. Harvey, L. (2019). "Analytic Quality Glossary." Retrieved March 30, 2019, from http://www.qualityresearchinternational.com/glossa ry/preliminarystudy.htm
24. Jain, R., & Ott, T. J. "NXG03-6: Design and Implementation of Split TCP in the Linux Kernel." In IEEE Globecom 2006 (pp. 1–6). IEEE.
25. Joshi, M., Mansata, A., Talauliker, S., & Beard, C. "Design and analysis of multi-level active queue management mechanisms for emergency traffic." Computer Communications, 28(2), 162–173, 2005.
26. Kandaswamy, C., & Ganapathi, P. "FloadAutoRED: an AQM scheme to Increase the Overall Performance in Internet Routers." International Journal of Computer Science Issues (IJCSI), 8(4), 308, 2011.
27. Kapadia, A. C., & Feng, W. "GREEN: a TCP equation-based approach to active queue management," 2004.
28. Kusano, T., Yamaguchi, K., Berberich, T., & Takahashi, Y. "Advances in polyamine research in 2007". Journal of Plant Research, 120(3), 345–350, 2007.