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***Research paper***

# A novel vertical handover algorithm based on Adaptive Neuro-Fuzzy Inference System (ANFIS)

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**Abstract**

Nowadays, there is an increased demand on an Internet connection anywhere at any time. Therefore, one has to exploit all available heterogeneous wireless networks where the target is achieving the Always Best Connected (ABC) among the different networks like UMTS, WiMAX, and WLAN. So, vertical handover techniques are used to ensure the best connectivity anywhere at any time. In this paper, novel ANFIS-based vertical handover is presented and compared with TOPSIS algorithm and other algorithms as a representative of Multi-criteria decision making (MCDM) algorithm's family. The simulation results show that the proposed handover technique provided better performance in terms of minimizing the time delay and improving the quality of service (QOS). This is because ANFIS requires iterations only in training phase otherwise, it has a much faster response. Our simulations considered the effect of many practical parameters on handover, such as subscriber speed, jitter, initial delay, bandwidth and received signal strength (RSS).According to these parameters, output values produced, which is utilized to choose the best candidate access network.

***Keywords***: *Vertical Handover; TOPSIS; MADM Method; ANFIS.*

## 1. Introduction

The next-generation of wireless systems represents a heterogeneous environment with different access networks technologies that differ in bandwidth, BER and cost. The handover has two types; Horizontal and vertical handover where horizontal handover occurs when mobile terminal changes between different cells of the same network while vertical handover is switching between different types of networks. Multi-criteria decision making (MCDM) algorithms in Heterogeneous Networks play an important role in choosing an alternative from a set of alternatives, which have the same criteria. The most popular MCDM methods are: SAW (Simple Additive Weighting), where the overall score of a candidate network is determined by summing the weights of all criteria values, TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) where the chosen best network is the one which is the closest to ideal solution and the farthest from the worst-case solution and AHP (Analytic Hierarchy Process) which decomposes the problem of choosing the network in many sub-problems and set the value of weight for each sub-problem. Handover technique has three phases:

- Handover information gathering: This phase is required to collect all information about the available networks and values of each criterion.
- Handover Decision: It is dedicated to determining the most suitable network.
- Handover Execution: It is responsible for changing to the selected network.

Some of the research work is mainly on handover decision phase to choose the best network. The first step calculates weights of the MN and network-related criteria using AHP. The second step ranks the performances of alternatives using SAW or TOPSIS. At present, many of the handover decision algorithms are proposed in the literature. In [1] Vertical handover performed by Analytic Hierarchy Process (AHP). This algorithm needs to adjust the attribute weights step by step, which results in a slow adjustment process and high-power consumption. An adaptive vertical handover algorithm based on the Analytic Hierarchy Process is proposed in [2] that can adjust the weights by the analytic hierarchy process. So it can save the power consumption. SAW algorithm is proposed to calculate the overall weight and select the largest one to perform a handover in [3, 4].GRA algorithm is considered in [5] to perform a vertical handover. TOPSIS algorithm is applied to the network selection process in [6]. The design of a fuzzy logic based vertical handover initiation scheme using a Fuzzy logic based Normalized Quantitative Decision (FNQD) to select an optimum access network between LTE and WiMAX is presented in [7]. Fuzzy logic and TOPSIS methods are used to reduce the number of handovers and increase user satisfaction [8]. In this paper, we implemented an ANFIS- based vertical handover scheme involving some parameters such as speed of MN(S), the bandwidth of the access network (BW), Network Traffic Load (NTL), Jitter (J), Bit Error Rate (BER) and initial time delay (ID). Training data of ANFIS based vertical handover decision making algorithm is obtained from TOPSIS algorithm. Simulations are made to observe the goal of creating a decision support system based on Adaptive Neuro-Fuzzy Inference System (ANFIS) between three alternatives (WLAN, UMTS and WiMAX). The differences of our study can be summarized as: (i) use three – ANFIS for three networks to reduce the time delay and get the decision quickly. (ii) Results of the proposed method have been compared with the traditional methods of vertical handover. The paper is organized as follows: Section two explains the methodology and the theoretical basis of the handover algorithms; Section 3 presents the simulation results together with its discussions and section 4 concludes the paper.

## 2. Methodology

Adaptive Neuro-Fuzzy Inference System (ANFIS) is the method of artificial intelligence, which connects fuzzy logic and neural networks into a single unit. The neural network in ANFIS system becomes the fuzzy system for reasoning. Those ANFIS construction modeling could be demonstrated looking into ANFIS network with two inputs (x and y) and one output (f). Sugeno fuzzy model with two rules is indicated by equations (1), (2).

$$\text{if x is } A_1 \text{ and y is } B_1, \text{then } f_1 = p_1x + q_1y + r_1 \quad (1)$$

$$\text{if x is } A_2 \text{ and y is } B_2, \text{then } f_2 = p_2x + q_2y + r_2 \quad (2)$$

Where $A_1$ , $A_2$ and $B_1$ , $B_2$ are the membership functions of each input x and y as part of the premises, while $p_1$, $q_1$, $r_1$ and $p_2$, $q_2$, $r_2$ are linear parameters. ANFIS architecture for two inputs x and y and one output f is depicted in Fig. 1, where it consists of five layers [9]; the first and fourth layers contain adaptive nodes, while the other layers contain fixed or non-adaptive nodes. The parameters $w_1$ and $w_2$ are the outputs of the second layer that represent the firing strength of each rule, while $\overline{w}_1$ and $\overline{w}_2$ are the normalized firing strength from the third layer.
The first step in creating this system was to gather all the necessary information about each criterion of every network. Each network has its ANFIS data and the corresponding output ranges from 1 to 7. MATLAB ANFIS Editor, anfisedit, was utilized and when loading the data as that in Fig. 2 to generate Fuzzy Inference System (FIS file),the automatic structure of ANFIS network and rules are created as well as a contrast from fuzzy which is needed to determine the membership functions and If-Then rules. In our model, there are three wireless networks to handover among them. The handover decision is based on six criteria for every network. They are RSS, NTL, ID, Jitter, Speed, and BW.

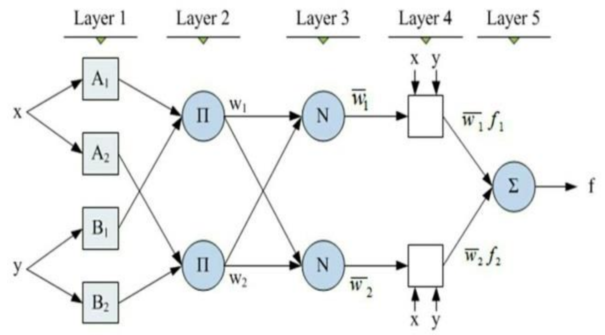


**Fig. 1:** ANFIS Architecture with Its Layers.

ANFIS has four steps:

1) Load data: When loading the training data from file or workspace, the data was loaded and plotted.
2) Generate FIS: This is the step of generating the fis file and the membership functions and its rules are determined to draw its structure. There are two methods; Grid partition and Sub-clustering. When choosing a sub-clustering method to determine the number of inputs of membership functions and their type differs from grid partition that is expected to decide the type of membership functions before generating the FIS file. There are 8 basic MATLAB membership functions [10] such as trimf, gbellmf, gaussmf, tramf, gauss2mf, pimf, dsigmf and psigmf.
3) Train FIS: When preparing the fis file, it requires two Epochs to determine the error. When increasing the number of Epochs, this error will be reduced.
4) Test FIS: The training data, testing data or checking data are tested and plotted when loading them. These steps are depicted in Fig. 3 which must be repeated for each network.

| 1 | RSS(dBm) | NTL(%) | ID(ms) | Jitter(ms) | Speed(m/s) | BW(Mbps) | output |
|---|---|---|---|---|---|---|---|
| 2 | -70 | 10 | 200 | 3 | 10 | 0.384 | 5 |
| 3 | -60 | 20 | 190 | 5 | 20 | 0.45 | 5 |
| 4 | -50 | 30 | 160 | 7 | 30 | 0.8 | 7 |
| 5 | -80 | 40 | 130 | 9 | 40 | 0.65 | 7 |
| 6 | -120 | 50 | 100 | 11 | 50 | 0.512 | 5 |
| 7 | -100 | 60 | 70 | 13 | 60 | 1.024 | 5 |
| 8 | -110 | 70 | 40 | 19 | 70 | 2.048 | 5 |
| 9 | -90 | 80 | 10 | 15 | 80 | 0.2 | 5 |
| 10 | -65 | 90 | 120 | 20 | 90 | 1.5 | 5 |
| 11 | .... | ...... | ......... | ...... | ..... | ...... | ....... |

**Fig. 2:** Section of the Table of Training Data to ANFIS.

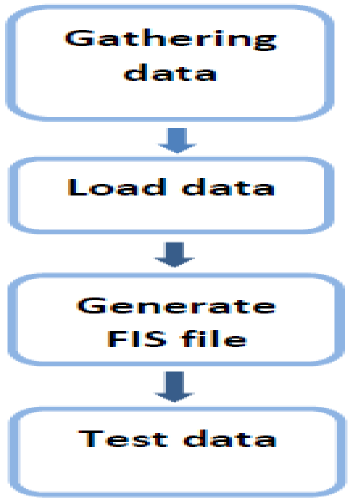


**Fig. 3:** The Steps for Producing Each Network.

The block diagram in fig. 4 shows the system model which contains an ANFIS for each network. In this work, three networks (WiMAX, UMTS and WLAN) are considered for network selection, and so three ANFIS subsystems are required and a comparator to compare the results of these ANFIS systems. WLAN networks have a lower delay and higher bandwidths while UMTS networks have lower bandwidths and delay is also large. Attributes of these networks and their ranges are shown in Table 1.

**Table 1:** Ranges of Attributes of Various Networks.

| | RSS (dBm) | NTL (%) | Initial delay (ms) | Jitter (ms) | Speed (m/s) | Bandwidth (Kbps) |
|---|---|---|---|---|---|---|
| WiMAX | -120 : -50 | 10-90 | 60-100 | 3-11 | 0-100 | 3000-10000 |
| UMTS | -120 : -50 | 10-90 | 10-200 | 3-20 | 0-100 | 384-2048 |
| WLAN | -120 : -50 | 10-90 | 10-160 | 3-11 | 0-100 | 1000-11000 |

Throughput, timeliness and reliability are the components of QOS. So, Bandwidth and NTL indicate throughput, Delay and jitter are a parameter of timeliness and Bit Error Rate (BER) is utilized to define reliability. The speed of the MN is a factor in the selection of the best network. In this paper, the priority criteria are assumed to decide the handover as:

(Speed = NTL) > (Bandwidth = Jitter) > (Initial Delay) > (BER)

NTL and speed are equally important and extremely to other criteria in the VHO decision. Jitter and Bandwidth are equally important. Initial Delay is more important than BER.

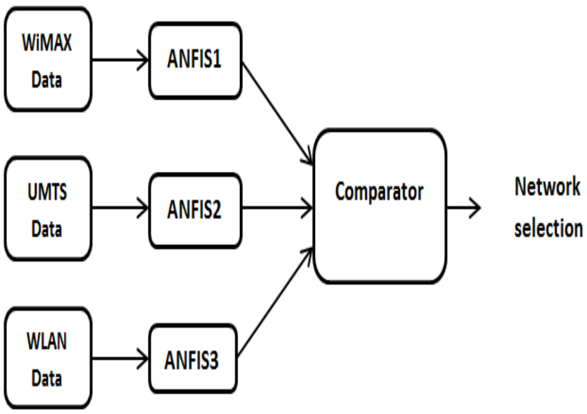


**Fig. 4:** The Block Diagram of the Vertical Handover System.

The sequence of the system goes after making the training data and generating the FIS through as pseudo code:

```
fis1=readfis ('WiMAX.fis')
fis2=readfis ('UMTS.fis')
fis3=readfis ('WLAN.fis')
Out1 = evalfis ([RSS NTL ID J S BW], fis1)
Out2 = evalfis ([RSS NTL ID J S BW], fis2)
Out3 = evalfis ([RSS NTL ID J S BW], fis3)
```

The detailed flow chart of the system is presented in fig. 5. After training the data of each network, the error was determined by testing it. If the error is high, the number of epochs can be increased to reduce this error while repeating the training and testing of the network until reaching to acceptable error. After this step; we can enter new data and check it. If the result after checking is not correct, the parameters for clustering can be changed while generating the ANFIS structure, and the next steps are repeated again. If the result is correct, the FIS file is ready. These steps are repeated to generate the FIS file for each network. After generating the three FIS files, new data can be entered, the outputs are compared and the network which has higher output is selected.

## 3. Resultsand discussion

In TOPSIS algorithm, the available networks are ranked by calculating the relative closeness $C_i^*$ in eq. (3) and the one having the higher score is selected as the best network.

$$C_i^* = \frac{\hat{S}_i}{S_i^* + \hat{S}_i} \ ; 0<C_i^*<1 \qquad (3)$$

$\hat{S}_i$is the separation from the negative ideal alternative and $S_i^*$ is the separation form ideal alternative which is calculated as in [6].The relative closeness index is calculated by varying speed between 0 to 100 km/h and keeping other parameters constant in rage of its attribute which are listed in Table 1 and the results were compared with the proposed algorithm. The output of ANFIS is in the range 1 to 7 that represents the probability of each network to hand over. Table 2 lists the meaning of the output number. When the output of each ANFIS network comes out, they are compared and the higher one is elected as the best one.

**Table 2:** The Meaning of ANFIS Output.

| ANFIS output | Means |
|---|---|
| 1 | Not prob. handover |
| 3 | Week prob. handover |
| 5 | Good prob. handover |
| 7 | Extremely prob. handover |
| 2,4,6 | Intermediate values |

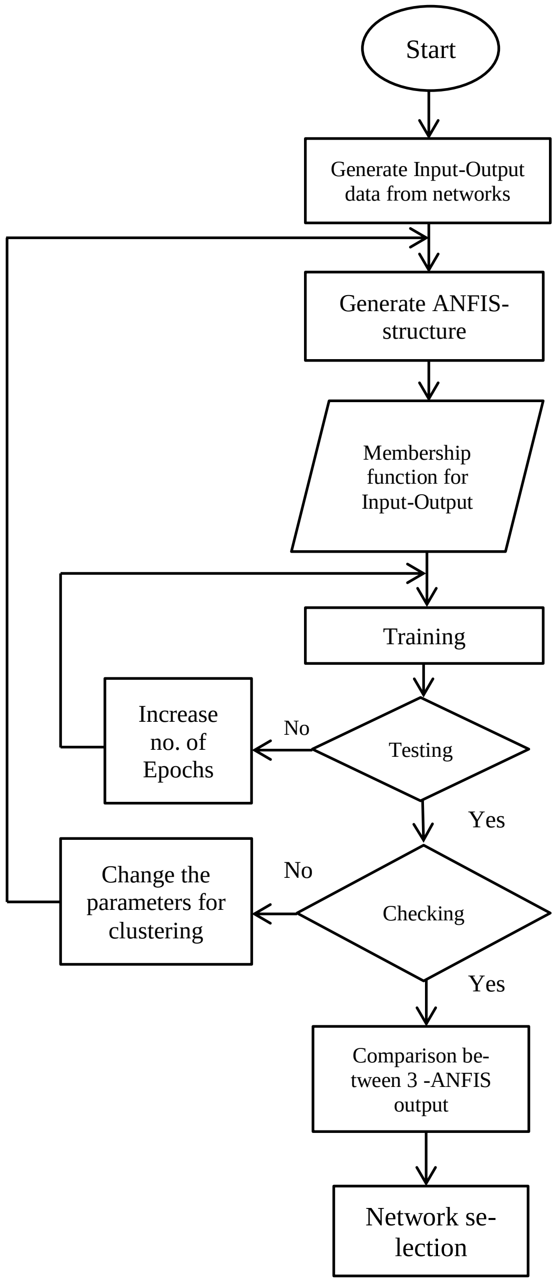


**Fig. 5:** Flowchart of the System.

Fig. 6, shows the output from the TOPSIS and the ANFIS algorithms with the same parameters of BW = [3415 909 8727] J = [9 5 4] RSS = [-114 -120 -90] ID = [86 148 90] NTL=40 as a function of the moving node speed.

One can see from the figure that UMTS network has a higher probability to handover from speed equal to 0 to 60 Km/h after that WiMAX should handover as it has a higher score to speeds up to 100 Km/h. It shows also, that the results of ANFIS are similar to the same of TOPSIS which verifies ANFIS.

In fig. 7, the vectors of parameters are as NTL=30 BW = [5106 1948 10810] J = [5 17 11] RSS = [-78 -58 -53] ID = [82 149 97], with only one change of the network load NL where it is reduced from 40 to 30.

The results of the handover probability are similar to the previous ones except for the value of the crossover UMTS and where it occurs at speed of 30 km/hour. Again the results of both handover algorithms are similar which verifies the ANFIS.

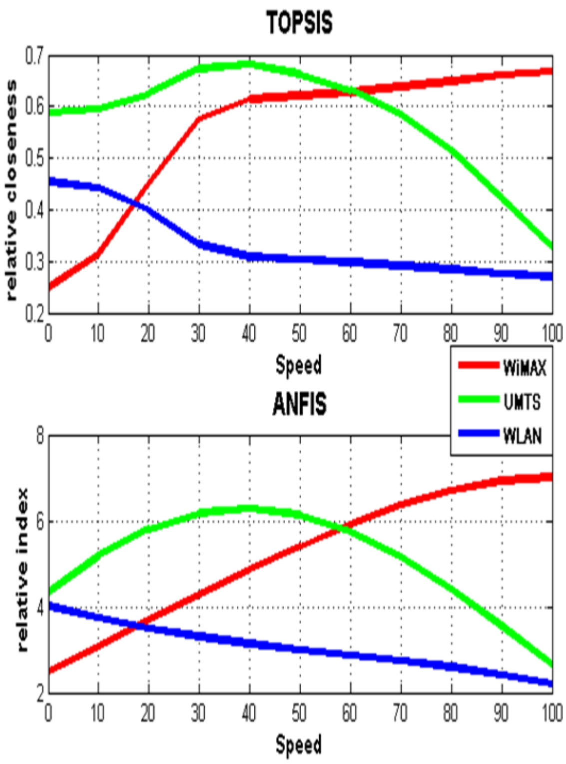


**Fig. 6:** Speed Vs. Relative Index in TOPSIS & ANFIS at NTL=40%.

Fig. 8 shows the plot of the handover probability versus the traffic load (NTL) varying from 10 to 90 at the vectors of parameters as BW = [5455 1947 9760] J = [7 14 8] RSS = [-106 -99 -87] ID = [69 171 39] and speed= 10 Km/h.

One sees from the figure that UMTS network has a higher score to handover for this vector of parameters over all NTL variations. WLAN and WiMAX participate in second place. The decision time is an important parameter when comparing the performance of handover algorithm designs. It is desired to have a minimum time delay of handoff while the requirements of the user, application, and network are satisfied. In this study, the proposed ANFIS based vertical handoff system is also compared with three algorithms; (i) TOPSIS algorithm; (ii) Simple additive weighting (SAW) method and (iii) The weighted-product method (WPM) [11]. To evaluate the speed of handover using ANFIS, the average time of TOPSIS taken to get one output decision is 2 ms while ANFIS takes 1 ms, SAW algorithm takes 1.8 ms and PWM algorithm takes 1.7 ms for the same input sequence as shown in Fig.9. According to block diagram of the system in Fig. 4, it is noticed that the three - ANFIS in parallel. This may be the cause of less time. So ANFIS algorithm is less time delay in vertical handover decision.
According to these results, the system based on ANFIS reduces the time delay by 50 % to improve the QOS and also it is simpler than the TOPSIS which takes more calculations in matrices. Likewise, the proposed algorithm is less complex than fuzzy algorithm as ANFIS decides the input membership function and its rules. However, in the fuzzy algorithm, the input membership function and its rules must be determined before starting.

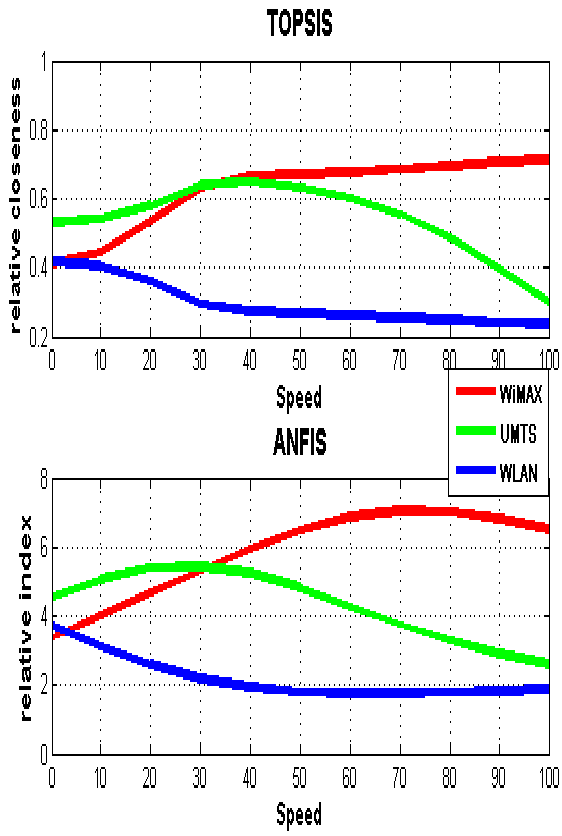


**Fig. 7:** Simulation of TOPSIS and ANFIS at NTL=30%.

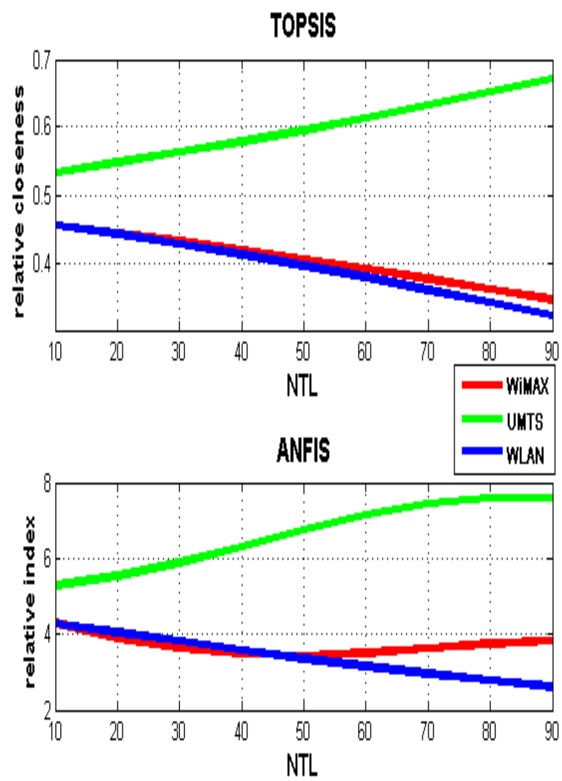


**Fig. 8:** NTL vs. Relative Index at Speed =10 Km/H.

## 4. Conclusion

In this work, a vertical handover decision support system has been realized with three - ANFIS networks that can indicate candidate network among WiMAX, UMTS and WLAN networks. ANFIS sub-clustering method is utilized to find the best FIS structure and determine the number of membership of inputs. Results show that ANFIS makes decisions like as TOPSIS but ANFIS is simpler in design and has less time delay that TOPSIS as it wastes time in calculating matrices and algebraic equations. ANFIS also is simpler than a fuzzy network that determines its membership and its rules. We have realized vertical handover based on ANFIS algorithm that can make decisions similar to the other algorithms but in a simple design, less time delay and higher speed by 50 % to conserve the QoS of the system.

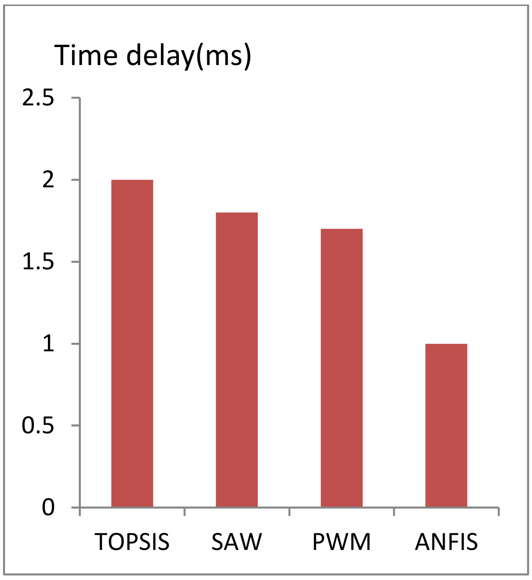


**Fig. 9:** The Time Delay Comparison in Algorithms.

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