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Simulation Model of Enhancing Performance of TCP/AQM Networks by Using Matlab

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Highlights:

- AQM is the traditional solution used to overcome such problems and to improve network performance under congestion.
- This work investigated the use of several different controllers in order to obtain the most suitable design through simulation, including a comparison of the selected types (GA, FLC & PID).
- This was done by testing the target queue by changing it with connection time and its relationship with the stability of the network.

Abstract. Internet networks are becoming more crowded every day due to the rapid development of modern life, which causes an increase in the demand for data circulating on the Internet. This creates several problems, such as buffer overflow of intermediate routers, and packet loss and time delay in packet delivery. The solution to these problems is to use a TCP/AQM system. The simulation results showed that there were differences in performance between the different controllers used. The proposed methods were simulated along with the required conditions in nonlinear systems to determine the best performance. It was found that the use of optimization Department of Electro-mechanical Engineering, University of Technology - Iraq tools (GA, FL) with a controller could achieve the best performance. The simulation results demonstrated the ability of the proposed methods to control the behavior of the system. The controller systems were simulated using Matlab/Simulink. The simulation results showed that the performance was better with the use of GA-PIDC compared to both FL-PIDC and PIDC in terms of stability time, height, and overrun ratio for a network with a variable queue that was targeted for comparison. The results were: the bypass ratio was 0, 3.3 and 21.8 the settling time was 0.002, 0.055, and 0.135; and the rise time was 0.001, 0.004 and 0.008 for GA-PIDC, FL-PIDC and PIDC, respectively. These results made it possible to compare the three control techniques.

Keywords: *AQM; FLC; GA; PID TCP.*

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1 Introduction

Congestion in Internet networks is becoming a real problem [1-3]. Network designers strive to reduce this problem through the use of modern control technologies. To achieve this goal, auxiliary factors must be weighed and considered. Researchers aim to reduce response time by regulating network congestion through network scheduling [4-6], focusing on several points. One point, for example, is placing the packages in a temporary storage that is linked to Network Interface Control Units (NICs). Additionally, researchers have used various algorithms, such as Explicit Congestion Notification (ECN) or Random Early Detection (RED) while running Active Queue Management (AQM) as best practice within router and switch systems.

The current problem of congestion within Internet networks leads to errors in data transfer. Therefore, the process of controlling congestion and correcting errors is critical. This can be done by using an appropriate application designed for controlling transmission, such as using the proper protocol (Transmission Control Protocol/Internet Protocol – TCP/IP). Many protocols have been added to the Internet as auxiliary units to control transmission. TCP/IP is one of the main protocols and works by tuning network parameters to avoid congestion [7-9]. Proportional-Integral (PI) and Proportional-Integral-Derivative (PID), PI & PID are other traditional control systems [10-12].

Many researchers have used traditional control systems in many applications, including TCP/IP networks. Fuzzy Logic Control (FLC) is a so-called expert system [13-15]. It acts as a control unit within different systems like TCP/IP networks to improve network performance. Studies have demonstrated the possibility of improving the performance of TCP/IP networks by adopting this type of control system.

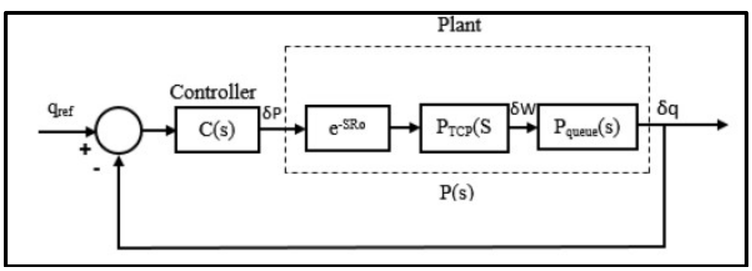

Figure 1 Block diagram for an AQM network system with controller.

The present research focused on simulating computer networks using real-time simulated loads and realistic systems. The use of appropriate algorithms to improve the performance of the systems, including genetic algorithms, was tested. Various scenarios were run to verify the validity or invalidity of using them. Traffic on any computer network within the Internet needs to be designed to plan for worst-case traffic. A mathematical representation was used to represent the system in developing a transformation function for the system using simulated system performance. Achieving the simulation goal with the possibility of representing the simulation in a computer program (Matlab) made it easy to verify the validity of the system's possible use by running the required tests [16-18]. Genetic algorithms (GA) are evolutionary algorithms that can be used to improve the performance of TCP networks or other systems [19-21]. They are considered an improvement technique to raise the level of efficiency of network systems for this type of work [22-24].

Jose& Mudholkar [25] used an FL controller to control congestion inside routers for TCP networks (traditional TCP-Africa algorithm) using an FL controller for queue delay. Lin, *et al.* [26] proposed to use two units of intelligent buffer overflow controllers (GAC and FLC) to optimize the performance of PIDC. The experimental results showed that GAC and FLC were more accurate and efficient than PIDC. The work depended on FSMC and GAs to control an AQM network to improve computer network performance by providing effective queue management [27]. Some studies have been conducted that simulated the adoption of non-linear systems, which is important in order to improve work performance by using traditional and expert control methods, which enables the researchers to control system behavior and obtain a balance with the changes in the operation of the system [24].

For the simulation, a model has to be chosen with specifications through which it is possible to find an appropriate design that simulates systems that operate in real time and to choose an appropriate controller to estimate the performance of the system's work. There are a number of performance measurement standards that are used in different control systems, such as (IAE), (ISE), (ITSE), and (ITAE). Control units can be designed to measure the error and reduce it to reach the desired response. ITAE, which can be considered one of the simplest and most time-saving performance measurement applications, measures and reduces predictable errors [28-30].

In this work, we attempted to enhance the performance of TCP networks by using AQM. This goal was achieved through a comparative study of several controllers through simulation using the Matlab program. A comparative study was done between PIDC, FL-PIDC and GA-PIDC to find out which controller provided the best performance for TCP network congestion management.

The rest of this paper is organized as follows: in Section 2 we discuss the system and mathematical model, in Section 3 we discuss the simulation of the system model, the simulation results are presented in Section 4, and Section 5 provides the conclusion of this work.

2 System and Mathematical Model

Figure 2 shows a model of a TCP/AQM network that includes source, router, and network parameters such as load factor = 60, sending = 700 packets, full-trip time = 0.25 sec, desired queue size = 300packets, maximum queue length in router 1 = 700 packets, link capacity = 15 Mbps (3750 packets/second link capacity), packet size = 500, propagation delay= 0.2 sec. Figure 3 shows a schematic model of a controller controlling the AQM network and a block diagram of the AQM network is shown in Figure 4 [31-33].

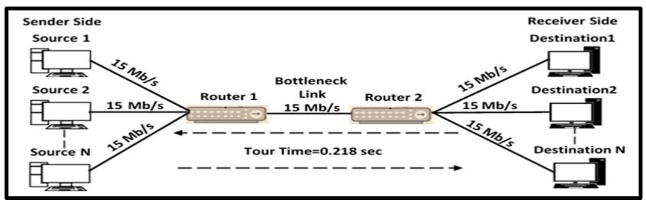

Figure 2 Model of the TCP/AQM network.

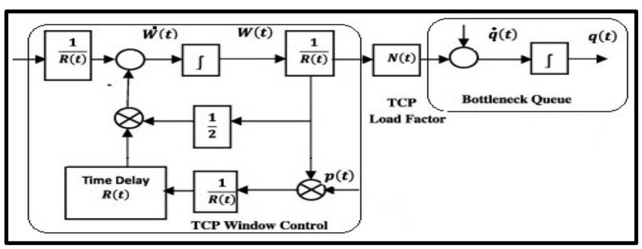

Figure 3 Schematic model of a controller controlling a TCP network [34-36].

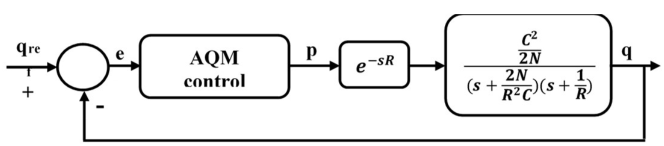

Figure 4 Block diagram of an AQM network

A dynamic model of a TCP network in a nonlinear system can be expressed as in Eqs. (1) and (2), which includes the elements of the dynamic model of the TCP network with the average queue length and the average TCP window size [37-39]:

$$"\dot{w}(t) = \frac{1}{\frac{q(t)}{C}+T_p} - \frac{w(t)}{2}\frac{w(t-R(t))}{\frac{q(t-R(t))}{C}+T_p}p(t-R(t))\ " \tag{1}$$

$$"\dot{q}(t) = \begin{cases} -C + \frac{N(t)}{\frac{q(t)}{C}+T_p}w(t) & \text{if } q(t) > 0 \\ \max\left\{0, -C + \frac{N(t)}{\frac{q(t)}{C}+T_p}w(t)\right\} & \text{if } q(t) = 0 \end{cases}\ " \tag{2}$$

where:

w = TCP window size, R=transfer rate of TCP measured in seconds = (q/C)+ T_p; q = queue length; C=capacity of the link; N=load factor; T_p = promulgation delay; p=packet sign probability.

Simulation using a required sampling time (0.125) by adopting a continuous system conversion function (Eq. (3)) is the T.F of this system [40]:

$$T.F = \frac{122.8s^3+3299s^2+2455s+3.252e^{04}}{s^4+1.136s^3+20.14\ \ ^2+1\ \ .26s+\ \ \ .8} \tag{3}$$

The T.F for the AQM model:

$$F(s) = \frac{q(s)}{p(s)} = \frac{\frac{C^2}{2N}e^{-sR}}{(s+\frac{2N}{R^2C})(s+\frac{1}{R})} \tag{4}$$

The nonlinear saturated input and time-delay scheme:

$$\text{sat}\big(p(t-R(t))\big) = \begin{cases} 1, & p(t-R(t)) \geq 1 \\ p(t-R(t)), & 0 \leq p(t-R(t)) < 1 \\ 0, & p(t-R(t)) < 0 \end{cases} \tag{5}$$

The input parameters for tuning the PID controller (FLC-PID) are (K_P, K_I, K_D and e). Eq. (6) describes the PID controller with an input e(t) and an output s(t) [34]

$$s(t) = K_P e(t) + K_I \int_0^t e(t)dt + K_D \frac{de(t)}{dt} \tag{6}$$

where:

e(t) = the error signal between the input reference and the process output; K_P = proportional constant gain; K_I = integral constant gain; K_D = derivative constant gain.

A block diagram of a Fuzzy Logic Controller with the T.F of a TCP network is shown in Figure 5.

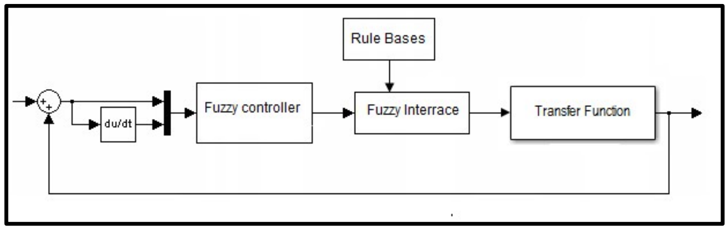

Figure 5 Block diagram of FLC with the T.F of a TCP network.

Fuzzy Logic Controller has several subsets of inputs and outputs, i.e., NB, NM, NS, Z, PS, PM, and PB, as shown in Figures 6-10, where NB = negative big, NM = negative medium, NS= negative small, Z = zero, PS = positive small, PM = positive medium, PB = positive big.

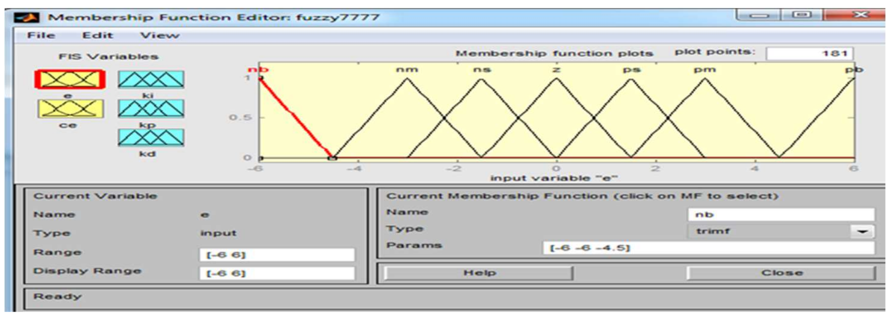

Figure 6 Simulation model of membership of (e) and (ce).

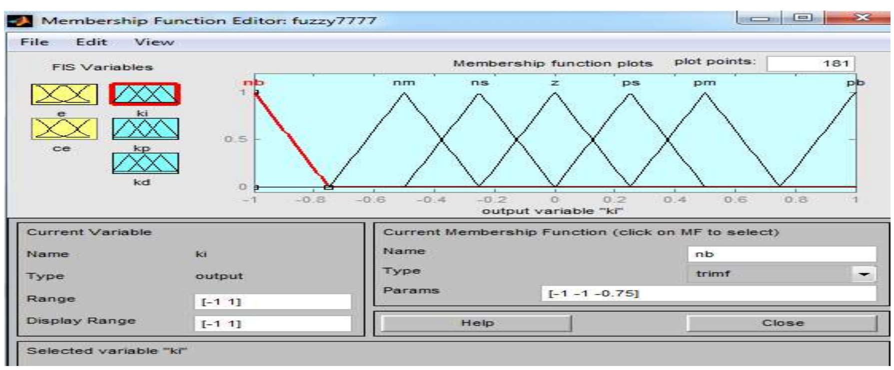

Figure 7 Simulation model of membership of Kp, Ki and Kd.

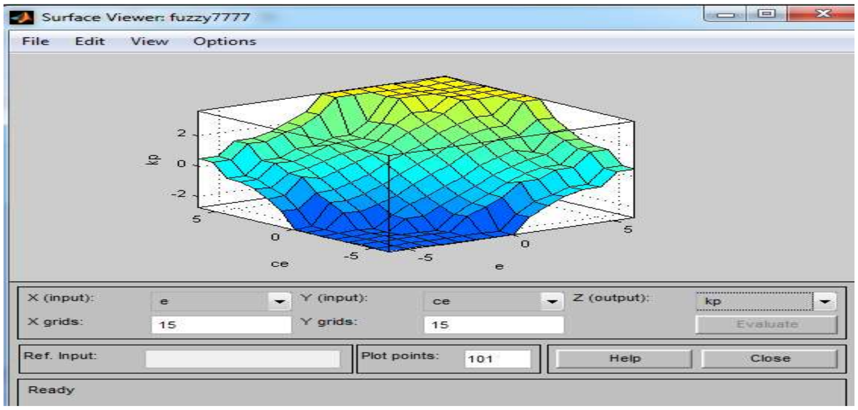

Figure 8 Simulation model of surface view of Kp, Ki and Kd.

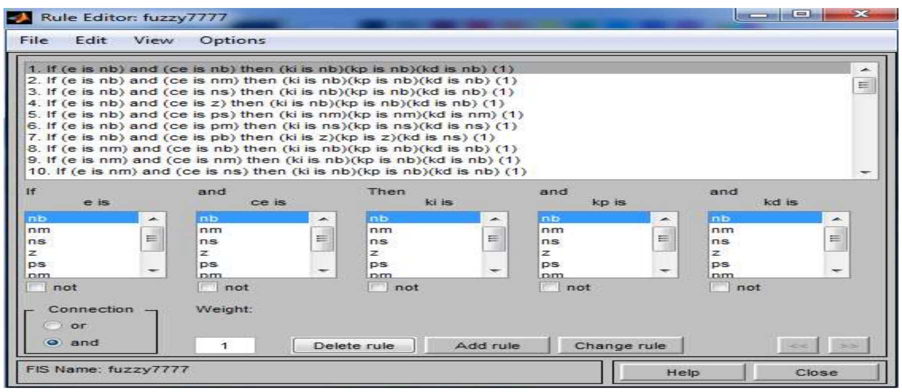

Figure 9 Simulation model of rule bases.

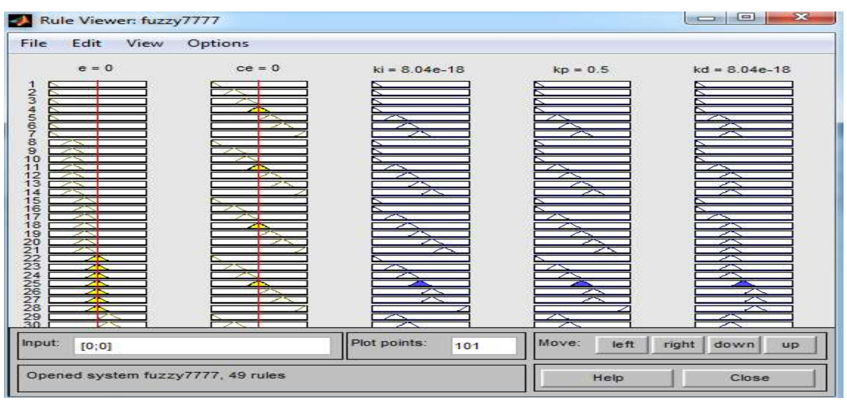

Figure 10 Simulation model of rule base view.

A block diagram of PIDC tuning using a genetic algorithm is shown in Figure 11.

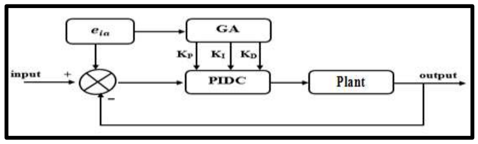

Figure 11 Block diagram of PIDC tuning using a GA.

Eq. (7) represents the process of converting and processing all chromosomes and Figure 12 shows a flowchart of the GA-PIDC.

$$C_v = L_b + \text{Dec}(\text{subseries}) \times \frac{(U_b - L_b)}{2^n - 1} \tag{7}$$

where: n=number of bits; U_b=upper bounds of the PIDC factors; L_b =lower bounds of the PIDC factors; C_v=real numbers of the PIDC factors; Dec(subseries) = decimal values of the bit series.

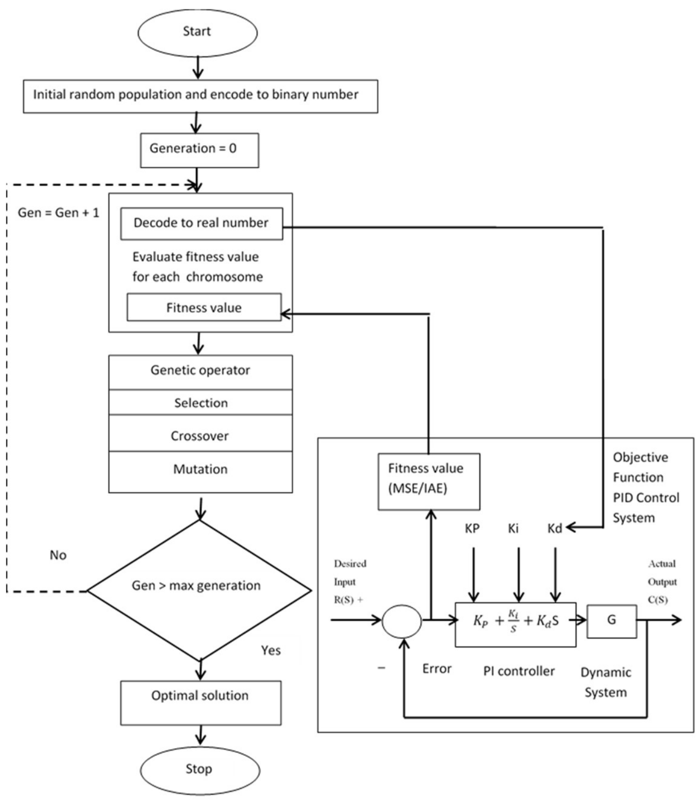

Figure 12 Flowchart of a GA-PID controller [35].

3 Simulation of the System Model

In this section, we present the simulation of the system model. The simulation model for TCP without a controller for constant and changing target queues is shown in Figure 13. The simulation model for TCP with PIDC for constant and changing target queues is shown in Figure 14. The simulation model for TCP with FLC-PID controller for constant and changing target queues is shown in Figure 15. The simulation model for TCP with a GA_PID controller is shown in Figure 16 as an M-file of Matlab.

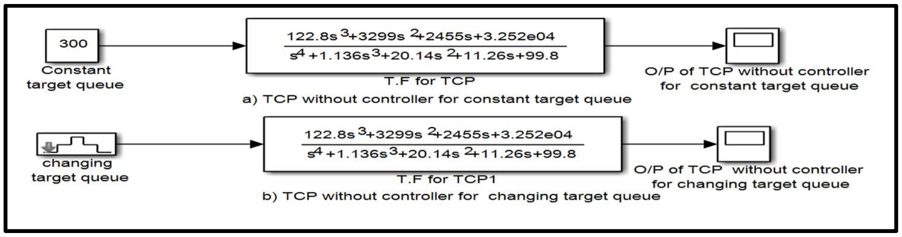

Figure 13 Simulation model for TCP without controller

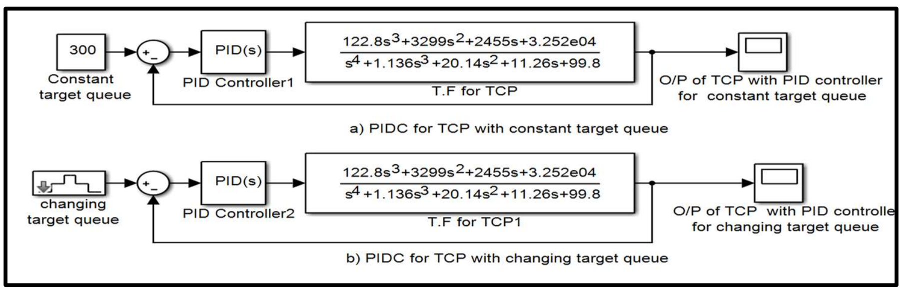

Figure 14 Simulation model for TCP with PIDC.

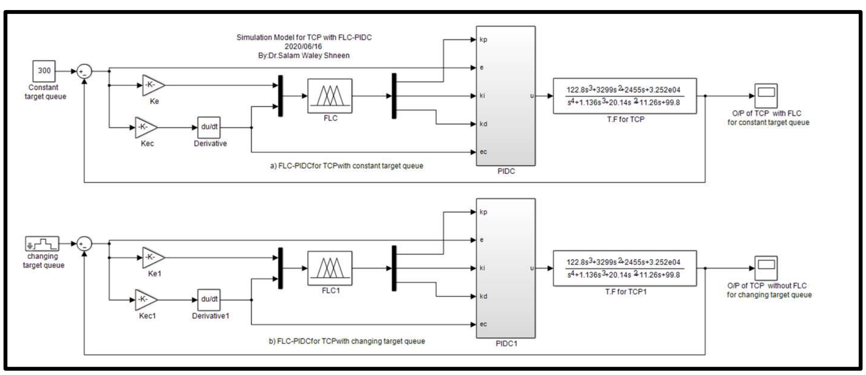

Figure 15 Simulation model for TCP with FLC-PIDC.

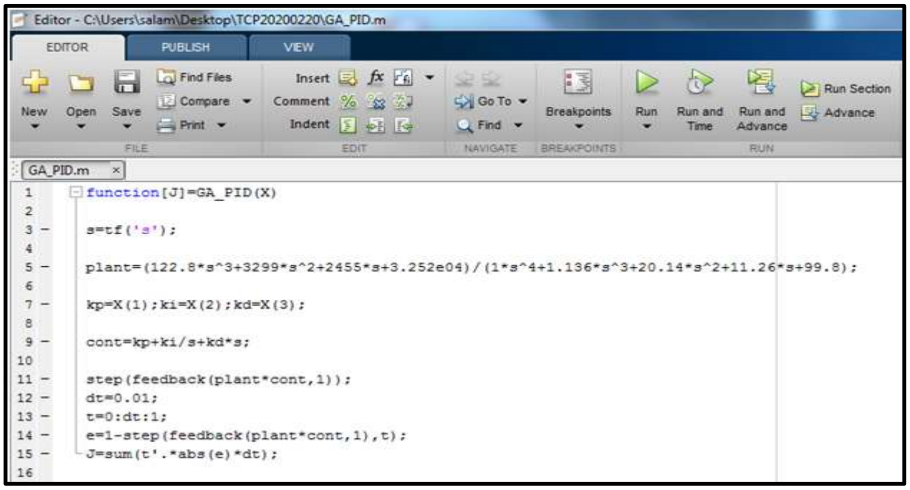

Figure 16 Simulation model for TCP with GA-PID.

4 Simulation Results

Simulations of the proposed system were done with each of the selected controllers in order to determine the best performance within the proposed working conditions. In the previous section, the proposed simulation models were developed to perform the experiments in this work. The results of the proposed cases are illustrated in the following forms.

For TCP without a controller, the simulation results are shown in Figures 17 and18 for two cases, a constant and a changing target queue, respectively.

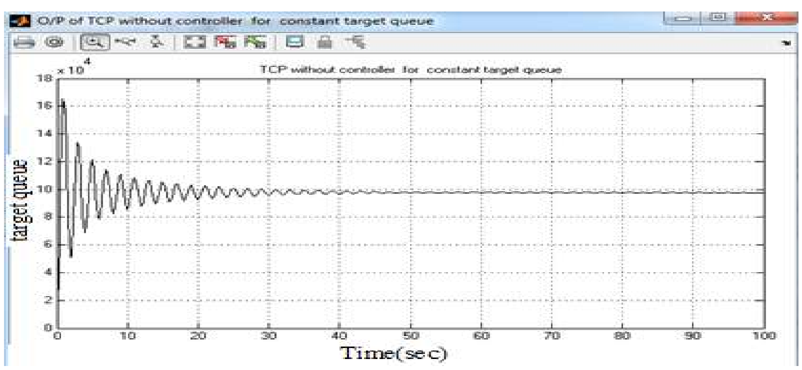

Figure 17 Simulation results for TCP without controller for a constant target queue.

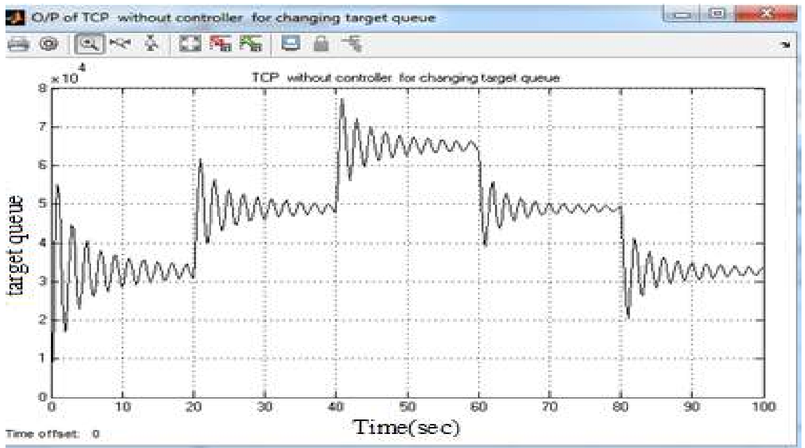

Figure 18 Simulation results for TCP without controller for a changing target queue for TCP with a PID controller.

The simulation results are shown in Figures 19 and 20 for two cases: a constant and a changing target queue, respectively.

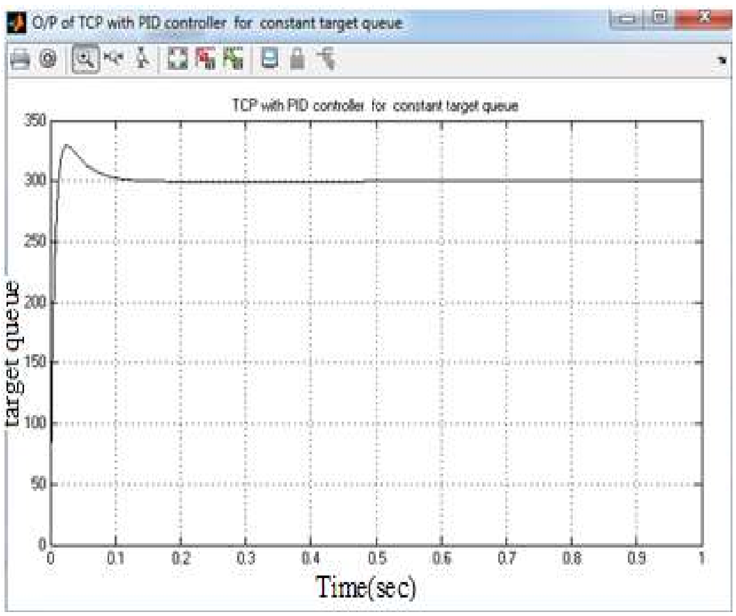

Figure 19 Simulation results for TCP with a PID controller for a constant target queue.

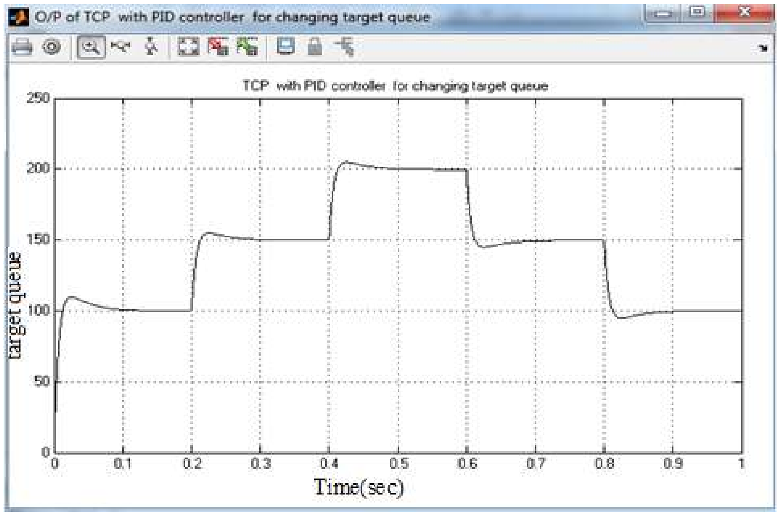

Figure 20 Simulation results for TCP with a PID Controller for a changing target queue. For TCP with a FL-PID controller, the simulation results are shown in Figures 21 and 22 for two cases, a constant and changing a target queue, respectively.

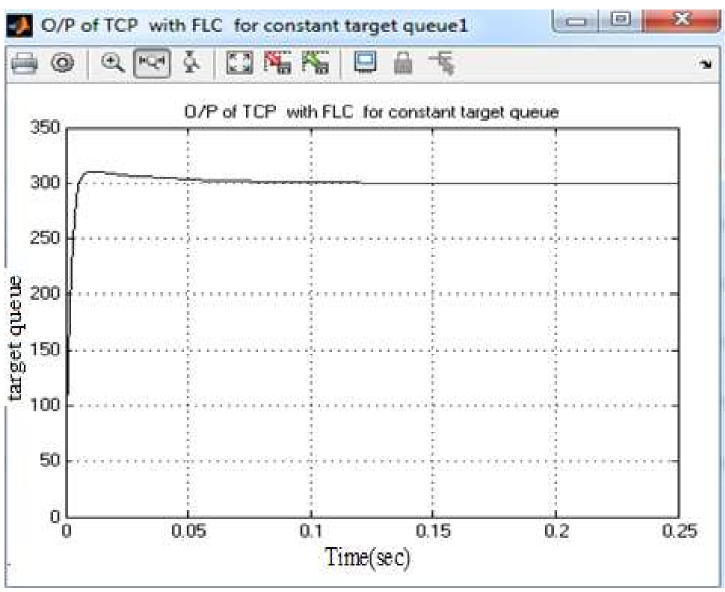

Figure 21 Simulation results for TCP with an FL-PID controller for a constant target queue.

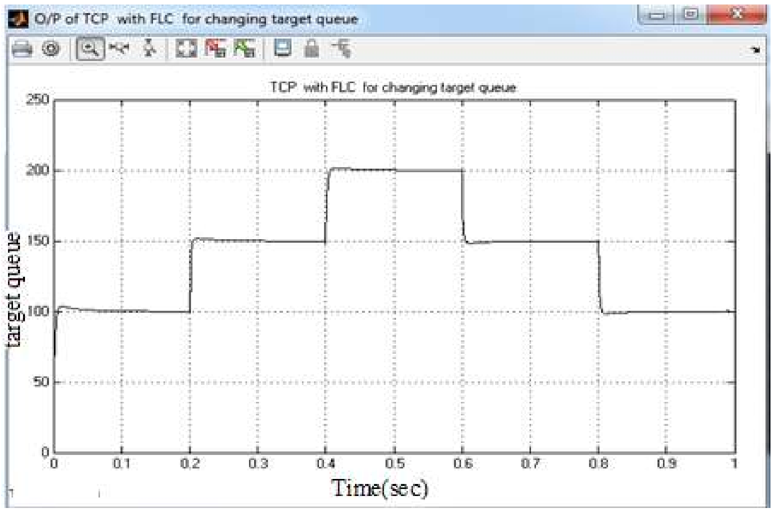

Figure 22 Simulation results for TCP with an FL-PID controller for a changing target queue for TCP with a GA-PID controller.

The simulation results are shown in Figures 23 and 24 for two cases, a constant and a changing target queue, respectively.

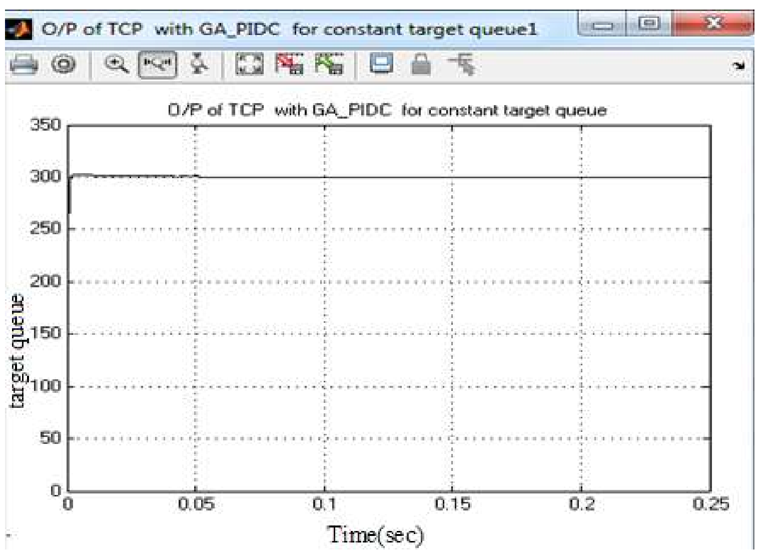

Figure 23 Simulation results for TCP with a GA-PID Controller for a constant target queue.

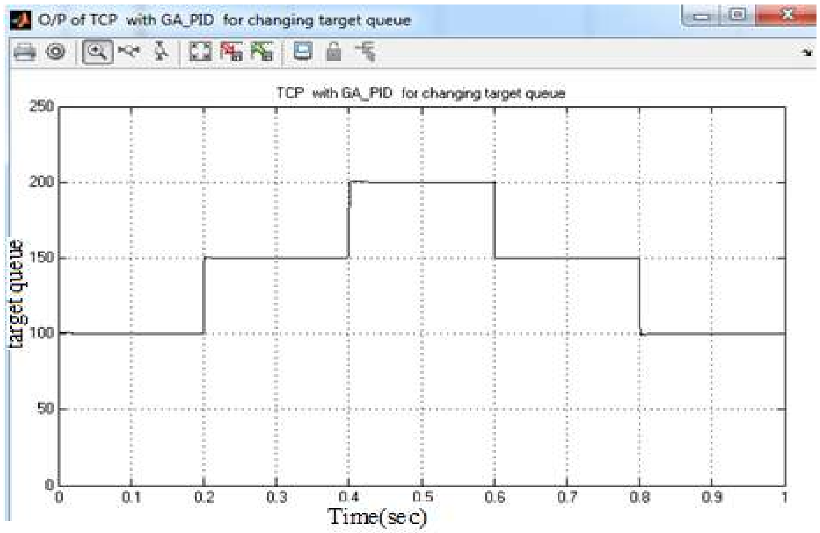

Figure 24 Simulation results for TCP with a GA-PID controller for a changing target queue.

Figures 25 and 26 show a comparison of the simulation responses for TCP with a GA-a PIDC, an FL-PIDC and a PID for a constant and a changing target queue respectively. Figure 25 shows the results of this work for a constant target queue based on which a comparison between the three controller techniques could be made. The rising time was 0.001, 0.004 and 0.008 for GA-PIDC, FL-PIDC and PIDC, respectively. The settling time was 0.002, 0.055 and 0.135 for GA-PIDC, FL-PIDC and PIDC, respectively. The overshooting percentage was 0, 3.3 and 21.8 for GA-PIDC, FL-PIDC and PIDC, respectively. Therefore, the performance of the TCP network was better when using GA-PIDC than FL-PIDC and PIDC, and FL-PIDC was better than PIDC. The same conclusion applies when using the three controller techniques with a variable target queue, as shown in Figure 26.

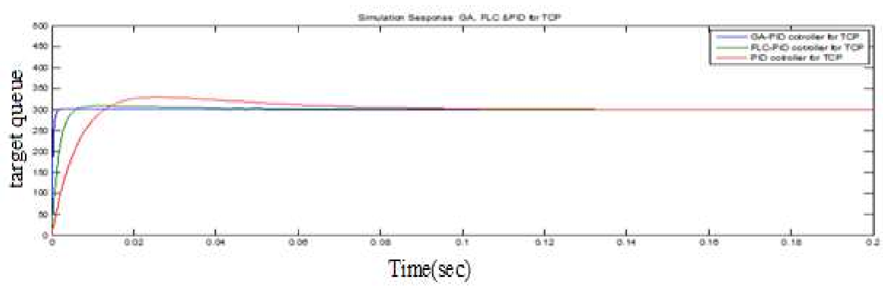

Figure 25 Simulation results for TCP with GA-PIDC, FL-PIDC and PIDC for a constant target queue.

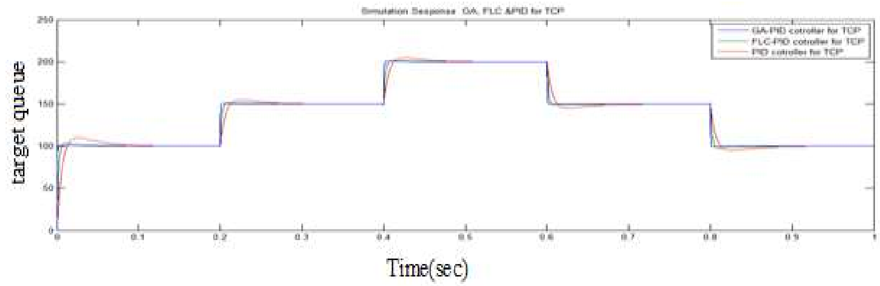

Figure 26 Simulation results for TCP with GA-PIDC, FL-PIDC and PIDC for changing target queue. Conclusion

5 Conclusion

Simulations of the proposed methods were performed using the most appropriate designs for all types of ACM control chosen for the specified working conditions. in a TCP network. The simulation results showed a marked difference in performance and response of the TCP network in avoiding network congestion, both with constant and variable queues. The results demonstrated the possibility of using any of the three controller types to improve the performance of the network, with a clear preference for the use of the genetic algorithm controller rather than the fuzzy logic controller or the PID controller. The fuzzy logic controller performed better than the PID controller.

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