Design and implementation of a stability control system for TCP/AQM network

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ABSTRACT

In this work, we used a new approach as active queue management (AQM) to avoid data congestion in TCP/IP networks. The new approach is PSO-PI controller which use the proportional-integral controller as a control unit and particle swarm optimization (PSO) algorithm as an optimization technique to improve the performance of the PI controller and therefore improving the performance of TCP/IP networks as a required goal. The optimization control (PSO-PI) is characterized by access to design and choosing the optimal parameters of (K_i andK_p) to reach optimal solutions in a short way (fewer iterations). The implementation of the PSO algorithm is achieving by using the mathematical system model and M-file and SIMULINK in Mathlab program. Simulation results show good congestion management performance with PSO-PI controller better than the PI controller as AQM in TCP networks, and the proposed method was very fast and required few iterations.

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1. INTRODUCTION

The increase in data circulating on the Internet and the increase in the number of Internet users has made the network more congested [1-3]. Among the problems that researchers work in the field of Internet use, such as buffer overflow for intermediate vectors, loss of packets and time delay in the delivery of packets [4-6]. To improve network performance, the use of transmission control protocol and active queue management (TCP / AQM). AQM was the main policy used for control [7-9]. To overcome these problems. The PSO algorithm is one of the distinctive methods used by researchers to solve nonlinearity and non-differentiation problems and to improve performance to reach adaptation [10-12]. The first to suggest PSO algorithm is Kennedy and Eberhart [13]. It is a method for developing flock research, such as gathering birds and keeping fish [14, 15]. The optimization PSO is characterized by a combination of algorithms that improve performance better than others, which are good efficiency, relative simplicity, and stable convergence property [16-18]. Design PSO-PID as a control unit for performance estimation using the ITAE standard as one of the simplest and most time-saving applications for performance measurement [19-21]. The ITSE performance standard weighs errors over time, penalizes small errors at a later time and distinguishes large initial error in response. To design controllers under the goal of trying to reduce system error resulting from several predictable inputs [22-24]. System error is the difference between the desired response and the actual system response. Among the approved standards that determine performance are those that are mainly based on the error scale in the system [25-27]. In general, traditional controllers such as PID can be designed in such a way as to use one of the formats of a performance standard that includes (IAE), (ISE), (ITSE) or (ITAE) in control [28-30].

Qaradawi, S. *et al.* they used a PI controller with PSO as an AQM to avoid the congestion in computer networks, the simulation results appeared a good response time with a constant value of output [31]. Nayl, T. M., *et al.* they proposed a design AQM for TCP network consisted of (LQ)-servo controller with PSO method to reduce the delay time, fostering settling time and provide a stable queue length [32]. Li, Z. H. E., *et al*, they suggested a new AQM approach for a type of TCP network by using an integral back-stepping technique (IB) and minimax procedure, the results showed a short convergent duration and deal with the disorders produced by UDP streams [33]. Kadhim, H. M., *et al,* they designed type-1 and type-2 fuzzy logic with PID controller to reduce the congestion in the TCP networks when they used optimization algorithms (PSO, SSO and ACO) to choose the parameters of two controllers, type-2 fuzzy logic with SSO has given good results [34].

This work proposes using a proportional integrity controller (PI) with algorithm (PSO) as an active queue manager for Internet routers. The goals of the work go toward fulfilling a stable queue length, improve latency to prevent TCP failure or slowing down. The structure of the paper is organized as follows, Section 2, include the Simulink model for TCP/AQM system. The simulation results wrote down in Section 3. The conclusion of this work wrote in Section 4.

2. SIMULINK MODEL FOR TCP/AQM SYSTEM

TCP/AQM network, in Figure 1 model System of TCP/AQM networks that includes routers, sources, and standardized control networks, Figure 2 schematic model System of a controller with AQM network and the system block diagram of TCP/AQM network in Figure 3.

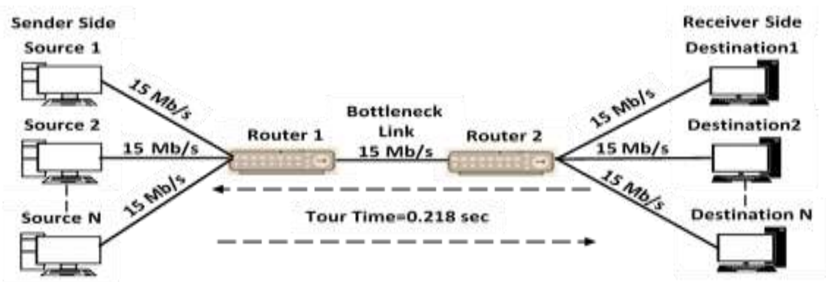

Figure 1. System of TCP / AQM networks

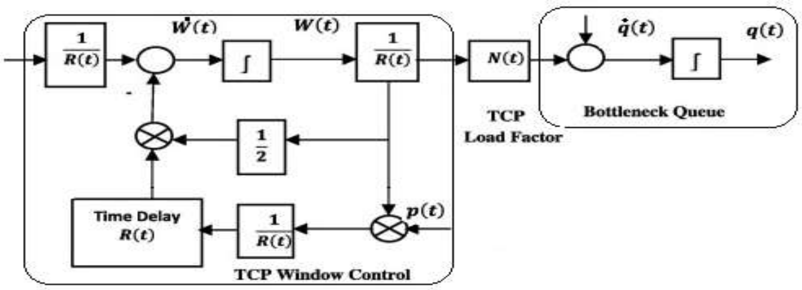

Figure 2. Schematic model of a controller with a TCP network

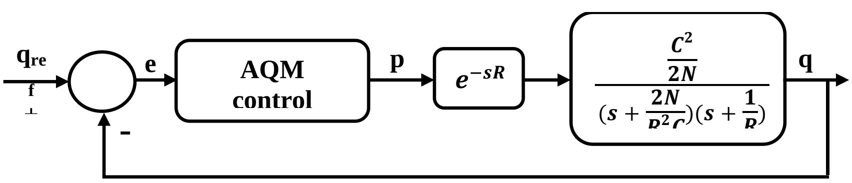

Figure 3. System block diagram of TCP/AQM network

In this section, it had two parts first part is the Simulink model of the PI controller for TCP/AQM that show in Figure 4. The Simulink model of PI for TCP/AQM, it had input, PI controller, T.F of TCP/AQM and output. The second part is the Simulink model of PSO-PI for TCP/AQM shown in Figure 5. The Simulink model of PSO-PI for TCP/AQM, it had input, PI controller with ITAE, T.F of TCP/AQM and output. Table 1 showing the values of TCP/AQM network topology that we have adopted on our work. The mathematical model of the TCP network as shown in (1-6) [35-38]:

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

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

$$\frac{122.8s^3+3299s^2+2455s+3.252e^{04}}{s^4+1.136s^3+20.14s^2+11.26s+99.8} \quad (3)$$

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

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

Where:
$\dot{w}$ and $\dot{q}$ is the time-derivative of w and q respectively.
w: Rate of TCP window size,
R: measured in seconds, R = $\frac{q}{C} + T_p$
q: rate of queue length
C: Capacity of the link
N: Load factor
T_p: Promulgation delay
p: Packet sign probability

$$s(t) = K_P e(t) + K_I \int_0^t e(t)dt \quad (6)$$

Where:
e(t): The error signal between (the input reference and the process output)
ec(t): The change of error signal
K_P: Proportional constant gain
K_I: Integral constant gain

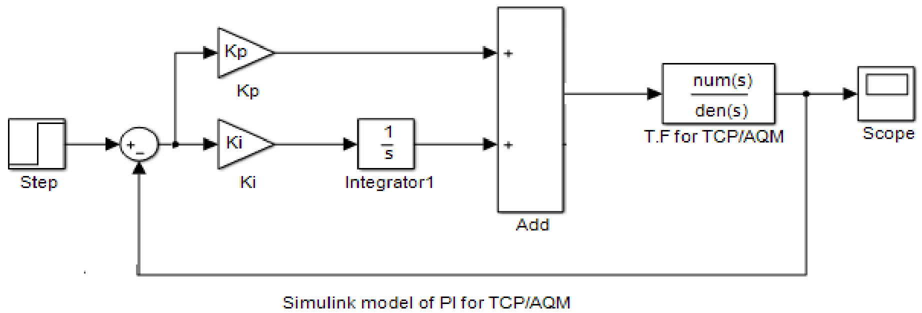

Figure 4. Simulink model of PI for TCP/AQM

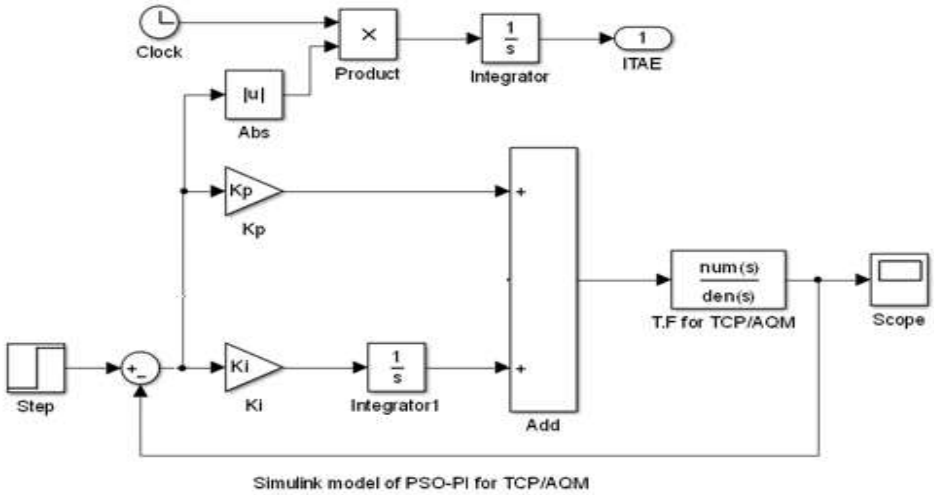

Figure 5. Simulink model of PSO-PI for TCP/AQM

Table 1. The TCP network parameter system

N	C	Packet size	Tp	R	q_{des}	q_{max}
60 (TCP session number)	15 Mbps (3750 packet/seconds link capacity)	500 byte -	0.2 seconds (the propagation delay)	0.253 seconds (the round-trip time)	300 packets (the desired queue size)	700 packets (maximumqueue length in router 1)

The traditional PI controllers are used in many applications for position and speed control, these controller methods need for re-tuning its parameters because it sometimes does not give better tuning and inclines to produce a large overshoot. To boost the abilities of PI parameter tuning, different intelligent techniques have been proposed to improve the PI tuning such as genetic algorithms (GA) [39-42], biogeography based optimization (BBO) [43-45], ant colony optimization (ACO) [46], bee colony optimization (BCO) [47], and PSO. The technique PSO was proposed in this work to tune the PI controller parameters to reach closely an optimal performance of PI controller to reduce the effect of congestion in TCP networks, for more details about PSO technique you can review Refs, [48-50]

3. SIMULATION RESULTS

In this section, the simulation results of this work are presented, it had two parts, the first part presents the Simulink results of PI controller for TCP/AQM that show through the Figures 6-9. The second part presents the Simulink results of PSO-PI controller for TCP/AQM that show in Figures 10, 11. The summary of all Simulink results was put in Table 2 with the important values that we got through Simulink circuits.

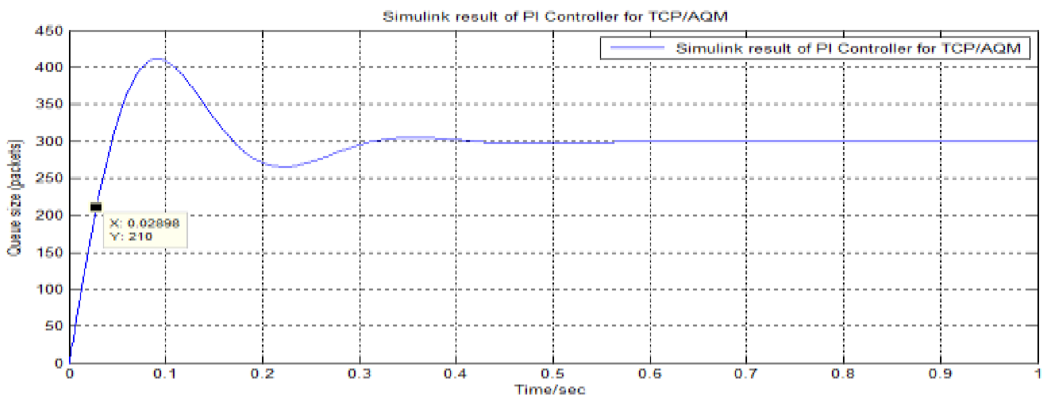

Figure 6. Simulation result of the PI controller for calculation of rising time (t_r.)

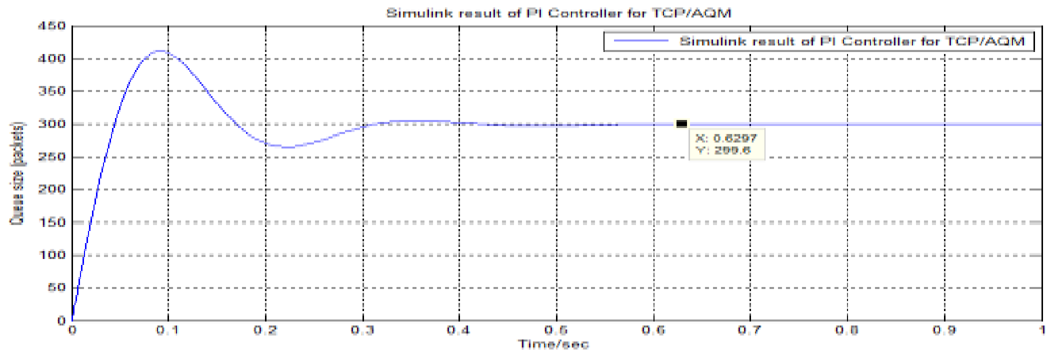

Figure 7. Simulation result of the PI controller at the calculation of steady state error (t_{ss}.)

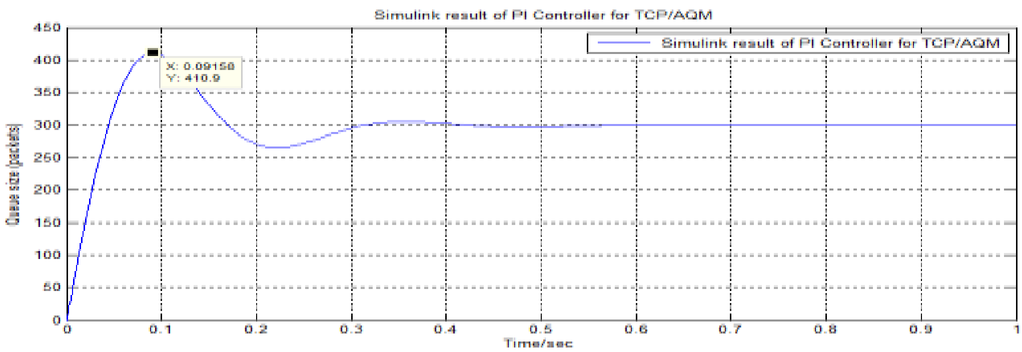

Figure 8. Simulation result PI controller for calculation of overshoot (%)

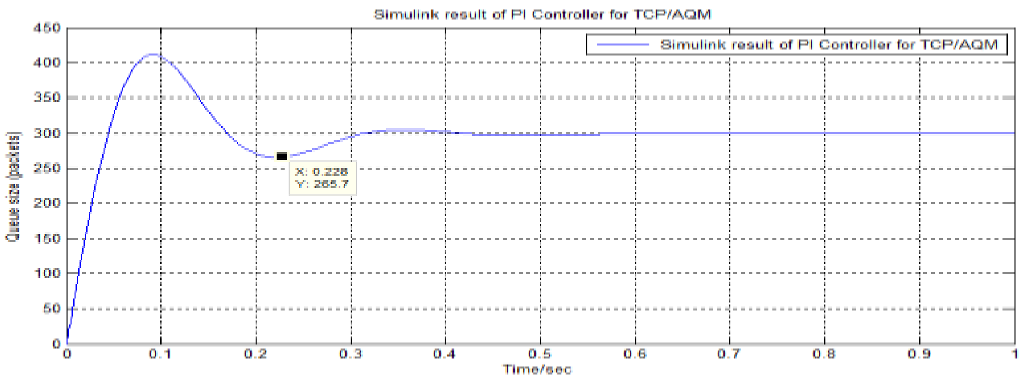

Figure 9. Simulation result PI controller for calculation of undershoot (%)

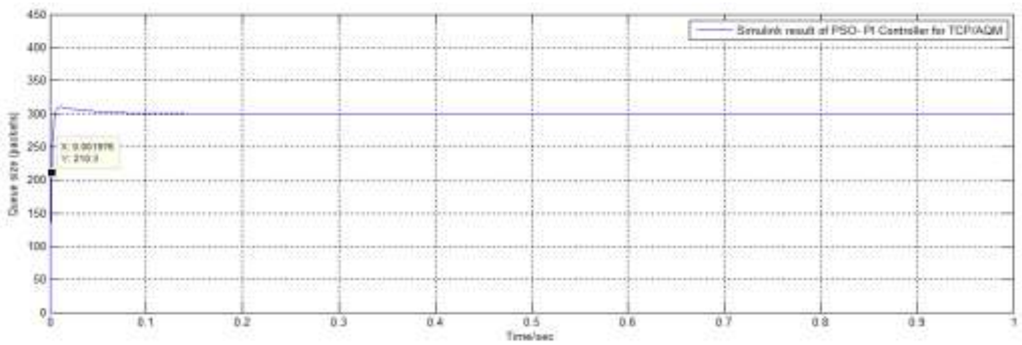

Figure 10. Simulation result of PSO-PI (ITAE) for calculation of rising time (t_r.)

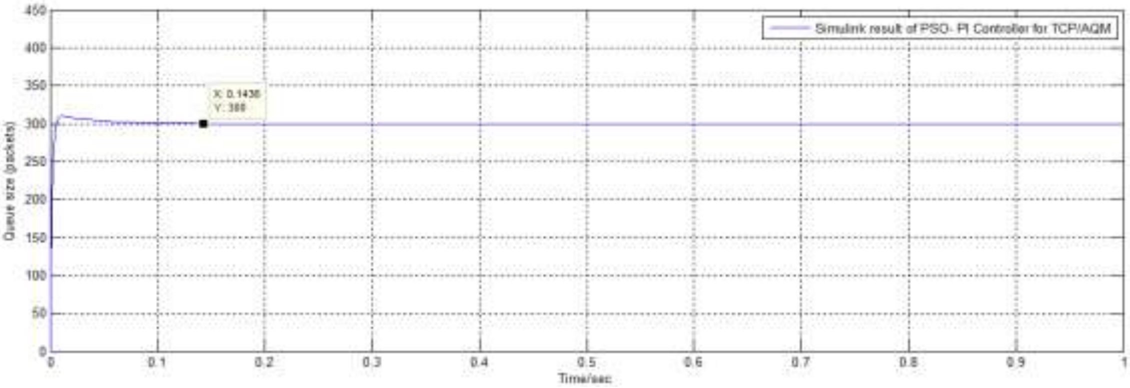

Figure 11. Simulation result of PSO-PI (ITAE) for calculation of steady state error (t_{ss}.)

Table 2. The details of the simulation results with the figures that show these results

Type of controller	X(time)/sec	Y (Queue size) (packets)	t_{ss}	t_r	Overshoot	Undershoot	Figure
Pi	0.02898	210		0.02898			6
Pi	0.6297	299.6	0.6297				7
Pi	0.09158	410.9			(0.09158, 410.9)		8
Pi	0.228	265.7				(0.228, 265.7)	9
Pso-pi	0.00197	210.3		0.00197			10
Pso-pi	0.1436	300	0.1436				11

Step response of the PSO- PI controlling system is completely different from that of the conventional PI controlling system. As shown in Figures 6-11 and Table 1. When using PI controller, the Rising Time Value = 0.02898, the Overshoot value = 410.9 at Time Value = 0.09158 and The Steady-State Error = 0.6297. While when using PSO-PI controller the Rising Time value = 0.00197, the Overshoot value = 309.5 at Time Value = 0.009366 and Steady-State Error = 0.1436. The values 0.02701, 0.4861 and 101.4 are represented the difference of values for rising time, steady-state error, and Overshoot respectively when using PI and PSO-PI, these three values show the rang of optimization in the performance of TCP/AQM system when used the PSO technique with PI controller. Remarkably, the PSO-PI controller has improved the force servo system by inferring the optimized k_p and k_i.

4. CONCLUSION

This work debate the design and implementation of the stability issue for TCP/AQM systems by using the PSO-PI controllers. According to simulation results, the designed PSO-PI controller can reduce the congestion problem with the best tracking execution for the desirable queue borders with high link exploitation and quicker response for the system. The simulation results showed that the step response of the PSO- PI controlling system is completely different from that of the conventional PI controlling system, the improvement in TCP/AQM systems work become clear especially if we note the difference between the values of rising time, steady-state error, and overshoot value in PI and PSO-PI controller. We can conclude that the use of PSO technique is very important to improve the performance of TCP/AQM systems due to the PSO-PI controller had improved the force servo system by deducing the optimized Kp and Ki.

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