Adaptive Fuzzy Logic in TCP/IP Networks using PID controller

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Abstract- **We introduce a novel and robust active queue management (AQM) scheme based on a fuzzy controller, called hybrid fuzzy-PID controller. In the TCP network, AQM is important to regulate the queue length by passing or dropping the packets at the intermediate routers. RED, PI, and PID algorithms have been used for AQM. But these algorithms show weaknesses in the detection and control of congestion under dynamically changing network situations. In this paper a novel Fuzzy-based proportional-integral derivative (PID) controller, which acts as an active queue manager (AQM) for Internet routers, is proposed. These controllers are used to reduce packet loss and improve network utilization in TCP/IP networks. A new hybrid controller is proposed and compared with traditional RED based controller. Simulations are carried out to demonstrate the effectiveness of the proposed method and show that, the new hybrid fuzzy PID controller provides better performance than random early detection (RED) and PID controllers.**

Keywords- **AQM, Fuzzy controller, Fuzzy PID controllers, PID controllers, adaptive hybrid controllers.**

I. INTRODUCTION

Internet is the fundamental part for running many new applications such as Web, multimedia, etc. However, due to unpredictability in interference and number of users who may access Internet in a given time congestion may result. This brings about long delays in data transmission and frequently makes the queue length in the buffer of intermediate routers to overflow, and even may lead to total network collapse. An active queue management (AQM) scheme is one of the efficient tools which detects inceptive congestion and gives early notice of current Internet situation by dropping (or marking) the incoming packets before router queues become full. Recently, many active queue management (AQM) schemes have been proposed to increase network utilization by regulating queues at the bottleneck links in TCP/IP networks, including Random early detection (RED) Adaptive RED (A-RED) , proportional-integral (PI) controller , and Random exponential marking (REM).Random early detection (RED) algorithm, the earliest well known AQM scheme, was proposed and is now used in the Internet routers for reducing the flow synchronization problem and calming the traffic load via the measurement of average queue length. Unfortunately, RED causes oscillations and instability in the network due to the parameter variations. Therefore, some modified RED schemes have been introduced in the literature. Proportional-integral-derivative (PID) feedback control is a practical and simple control approach for controller design. This approach has been used to design and analyze various present AQM schemes in Internet congestion control.

PID controllers are designed for linear systems and they provide a preferable cost/benefit ratio. However, the presences of nonlinear effects limit their performances. Fuzzy controllers are successful applied to non-linear system because of their knowledge based nonlinear structural characteristics. Hybridization of these two controller structures comes to one's mind immediately to exploit the beneficial sides of both categories. Naturally various hybrid controller structures have been arisen in literature. In some applications, these two control structures are combined by a switch. In a fuzzy switching method between fuzzy controller and conventional PID controllers is used to achieve smooth control during switching.

II. EXISTING SYSTEM

The RED active queue management algorithm allows network operators to simultaneously achieve high throughput and low average delay. However, the resulting average queue length is quite sensitive to the level of congestion and to the RED parameter settings, and is therefore not predictable in advance. Delay as a major component of the quality of service delivered to customers, is used by network operators to give a rough a-priori estimate of the congestion in routers. To achieve such predictable average delays, RED would require constant tuning of the parameters to current traffic conditions. Since the RED-based algorithms control the macroscopic behavior of the queue length (average), they often cause sluggish response and fluctuations in the instantaneous queue length. As a result, an important change in end to end delays is observed. As a consequence, RED and its variants provoke dramatic consequences on sensitive flows.

III. PROPOSED SYSTEM

The control theoretic techniques have been lately introduced in flow control and congestion avoidance. These recently developed mechanisms outperform the existing Works. Whereas classical approaches are rather informal, they give the

necessary means to explicitly specify multi criterion performance. These alternative methods model the AQM algorithm as a feedback control system that tunes the router queue length as a plant variable. Among the contributors to control-theoretic flow control, proposed use of the PID controller which is widely used in automatic control systems. In feedback Compensation element was introduced in order to provide a more robust controller under time-varying network conditions. Besides that, in a variable structure based control scheme was used to take into account the model uncertainties and the number of active TCP connections. These controllers permit better performance in compared with REDs. For instance, the PID controller adds to the integral control, a proportional control for a faster response, and a derivative control for anticipated congestion avoidance. The theoretic control in the network management domain brings some new alternatives which permit good performance in router throughput and better management in queue length. PID controllers are designed for linear systems and provide a preferable cost/benefit ratio. However, the presences of nonlinear effects limit their performances. On the other hand Fuzzy controllers are successfully applied to non-linear systems because of their knowledge based nonlinear structural characteristics. Hybridization of these two controllers brings to one's mind immediately to exploit the advantages of both categories.

TRANSMISSION CONTROL PROTOCOL

TCP means "Transmission Control Protocol". It is an "end-to-end" communication protocol, which means that a direct link between the source and the destination is established. The main characteristic of this protocol is to verify the data reception by the receiver, using mechanism based on acknowledgement. If a packet is lost, the sender should send it again. Thus TCP assures the transmission of the entire information.TCP is a general purpose protocol, and does not make assumption on the network used. To find the maximum transmission throughput, TCP probes the network until reaching the limit. This is the role of slow start and congestion avoidance mechanisms.

MODELING

The overall system is an interconnected feedback system as described by the Figure.

Thus feedback control principle appears to be an appropriate tool for the analysis and design of AQM strategies.

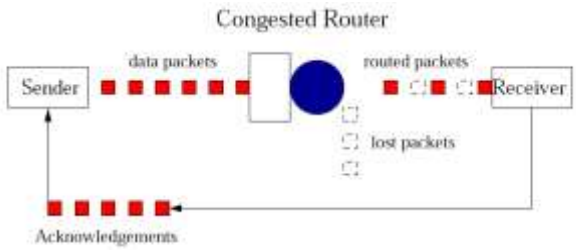

Figure :The considered system

PID CONTROLLER

A proportional-integral-derivative controller (PID controller) is a control loop feedback mechanism (controller) widely used in industrial control systems. A PID controller calculates an error value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error by adjusting the process through use of a manipulated variable.

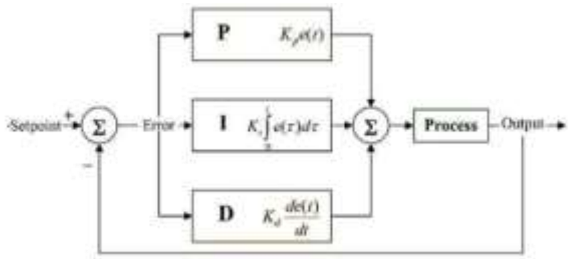

Figure block diagram of PID controller

The PID controller algorithm involves three separate constant parameters, and is accordingly sometimes called three-term control: the proportional, the integral and derivative values, denoted P, I, and D. Simply put, these values can be interpreted in terms of time: P depends on the present error, I on the accumulation of past errors, and D is a prediction of future errors, based on current rate of change. The weighted sum of these three actions is used to adjust the process via a control element such as the position of a control valve, a damper, or the power supplied to a heating element.

HYBRID FUZZY-PID CONTROLLER

In this paper, the classical PID and fuzzy PID controller are combined by a blending mechanism that depends on a certain function of actuating error. Moreover, an intelligent switching scheme is induced on the blending mechanism that makes a decision on the priority of the two controller parts; namely, the classical PID and the fuzzy constituents. The parameters of the PID controller are denoted by K, TI, and TD. As encountered in the literature, these stand for proportional gain, integral and derivative time constants, respectively. The parameters of the fuzzy controller are defined as Ke, Kd, α , and β .

FUZZY LOGIC & FUZZY CONTROL:

Fuzzy logic is a form of logic that is the extension of Boolean logic, which incorporates partial values of truth. Instead of sentences being "completely true" or "completely false," they are assigned a value that represents their degree of truth. In fuzzy systems, values are indicated by a number (called a truth value) in the range from 0 to 1, where 0.0 represents absolute false and 1.0 represents absolute truth.

Fuzzy logic has become a common well known word in machine control. However, the term itself provides certain skepticism, sounding equivalent to half-baked logic or ambiguous logic. Fuzzy logic is a way of interfacing analog processes that move through a continuous range of values, to a digital computer, that seems to be well-defined discrete numeric values.

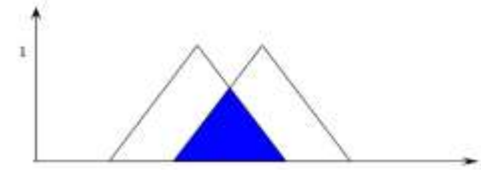

Figure Intersection of fuzzy sets A and B

Han Xiong Li et.al, has proposed a two dimensional configuration for PID type FLC. In this paper optimal fuzzy reasoning model for control is proposed and is compared with conventional fuzzy control

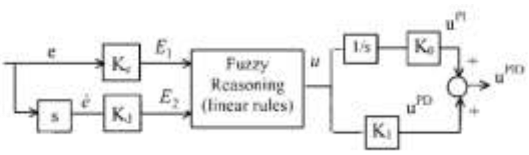

Figure Architecture of fuzzy PID controller

PROPOSED HYBRID FUZZY PID CONTROLLER

This section gives a detail view of hybrid fuzzy PID controller. Figure 5.13 shows the parallel form of PID controller where all the elements (proportional, integral and derivative) are summed together to produce the control effect.

A standard PID controller is also known as the “three-term” controller, whose transfer function is generally written in the “ideal form” as

$$G_{PID}(s) = K\left(1 + \frac{1}{T_I s} + T_D s\right)$$

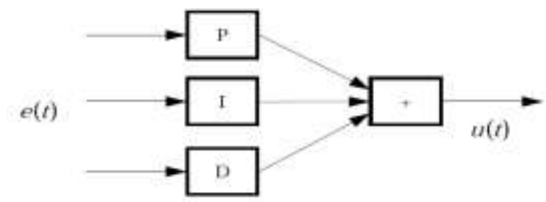

Figure: conventional PID controller

The proposed hybrid controller that is given in Fig.5.14 possesses two main parts: the classical PID and fuzzy PID controllers.

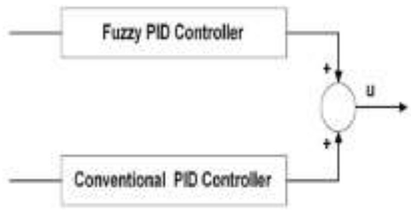

Figure: Block diagram of hybrid type fuzzy PID controller.

where K is the proportional gain, KI the integral gain, KD the derivative gain, TI the integral time constant and, TD the derivative time constant. The “three-term” functionalities are highlighted by the following:

The proportional term is providing an overall control action proportional to the error signal through the all-pass gain factor.

The integral term is reducing steady-state errors through low-frequency compensation by an integrator.

The derivative term is improving transient response through high-frequency compensation by a differentiator.

The structure of the fuzzy PID controller, which has two inputs and one rule base, is shown in Fig. 5.15. The inputs are the classical error (e) and the rate of the change of error (ė).

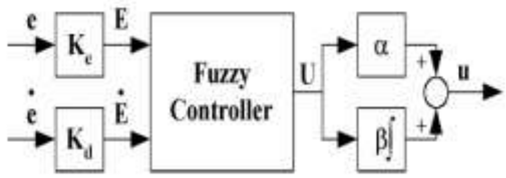

Figure The Fuzzy PID Controller structure

Triangular membership functions are used for input variables.The fuzzy PID controller rule base composed of 49 (7x7) rules as shown in Table 5.2

The linguistic variables used in the membership functions are described in table 1.

Table: Linguistic variables in fuzzy inference system

Error e(t)	Change in error Δe(t)	Controller output u(t)
Negative Big(NB)	Negative Big(NB)	Negative Big(NB)
Negative Medium(NM)	Negative Medium(NM)	Negative Medium(NM)
Negative Small(NS)	Negative Small(NS)	Negative Small(NS)
Zero(ZO)	Zero(ZO)	Zero(ZO)
Positive Small(PS)	Positive Small(PS)	Positive Small(PS)
Positive Medium(PM)	Positive Medium(PM)	Positive Medium(PM)
Positive Big(PB)	Positive Big(PB)	Positive Big(PB)

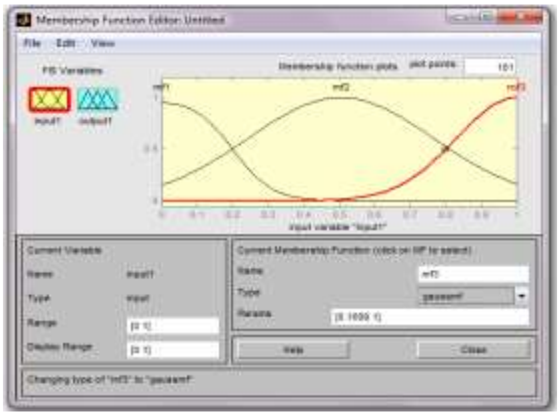

Figure: Membership Function Editor

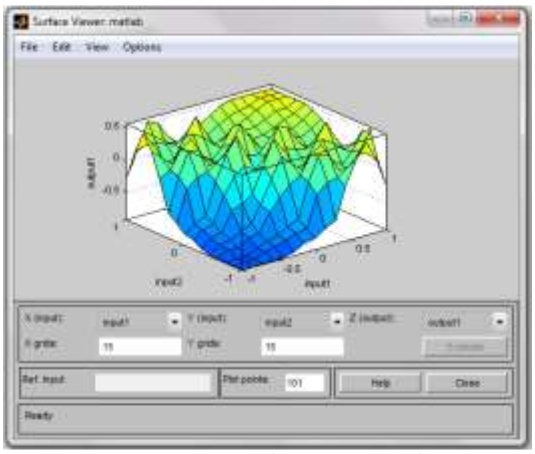

Fig: Three dimensional plot of the control surface

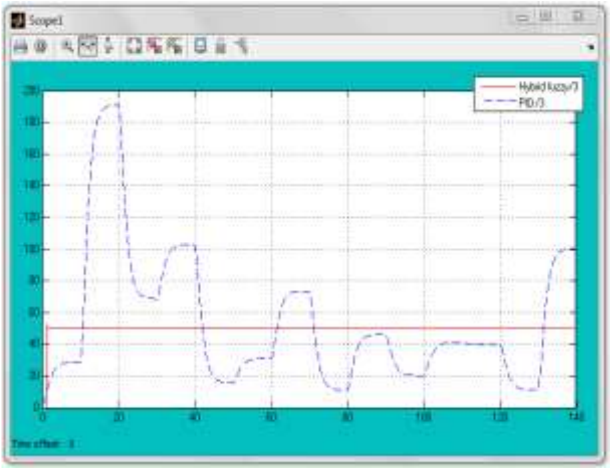

Figure Instantaneous queue length

CONCLUSION

A new AQM scheme using fuzzy logic techniques is proposed, which is refer to as Hybrid Fuzzy PID controller. It can be implemented in TCP/IP networks to provide effective congestion control for high utilization, low losses and delays which are very important for multimedia applications. Hybrid Fuzzy controllers behave better than other AQM schemes in terms of queue fluctuations and delay, loss and link utilization of packets in TCP/IP networks. Obtained results show that Hybrid Fuzzy Control methodology will offer significant improvements on controlling congestion in TCP/IP networks. It permits a very fast response in compared with the classical adaptive controllers, RED and PID. In the future work, we can use intelligent algorithm for drive PID coefficients to further improve the performance of our algorithm.

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