International Journal of Scientific Research & Engineering Trends
Volume 1, Issue 5, Sept.-2015, ISSN (Online): 2395-566X

# Improving Congestion Control in Internet Networks using Fuzzy Logic Congestion Controller

**C . A. Mgbachi**
Electrical/Electronic Engg. Department,
Enugu State University of Science and
Technology ESUT Enugu- Nigeria.
Email: Cysmart2007@yahoo.com

**I. I. Eneh**
Electrical/Electronic Engineering
Department, Enugu State University of
Science and Technology ESUT Enugu-
Nigeria.

**Ameh, E. M.**
Metallurgical and Material Engineering
Department, Enugu State University of
Science and Technology ESUT Enugu-
Nigeria.

***Abstract* – There exists great demand supporting ever-increasing new Internet applications such as voice over IP and video on demand. Thus it becomes necessary to design effective congestion control and queue management algorithms to handle this. However, such a design is known to be difficult because there are a variety of services supported in the Internet and their various demands for Quality of Service (QoS). This led to a new trend in using alternative techniques, such as Fuzzy Logic Controllers (FLC) which have the ability to cope with the aforementioned problems and provide more flexibility in modeling congestion controllers as well. An improved Fuzzy algorithm is employed to derive optimal or near optimal PID control gains such that the error between the router queue length and the desired queue length is minimized. Basically, in this new methodology, the classical PID and fuzzy controller have been combined by a blending mechanism which depends on a certain function of actuating error. A simulation study over a wide range of traffic conditions shows that the FEM In/Out controller outperforms the Random Early Detection (RED) implementation for Diff-Serv in terms of link utilization, packet losses, and queue fluctuations and delays.**

***Keywords* – Fuzzy Logic Control, TCP/IP, AQM, Congestion Control, Active Queue Management (AQM), Quality of Services *(QoS)*.**

## I. INTRODUCTION

Congestion describes a situation where there exists waiting due to some abnormalities in the flow system. In our road network system for instance, congestion may be due to rush hour, bad road, accident or indiscipline on the part of road users. In the internet network system, congestion can be due to overload on the network resources due to delays and astomical increase in the network resourcses demand. Under this situation too many datagrams are present in buffers that hold the packets/datagrams before and after processing in the Internet system. Internet network system congestion may occur if the number of datagrams sent by the source computers are beyond the rated capacity of the network or routers causing waitings. Under this situation, there will be embarrasing quenes on the routers and switches.

*"When an increase in the use of a facility or service (in this case internet network resources) which is used by a number of people would impose a cost (not necessarily a monetary cost) on the existing users, that facility is said to be 'congested'.* Steven Bauer ( 1987)

Congestion is also traced to saturation of network resources like communication links, buffers, network switches, etc. For example, if a communication link delivers packets to a queue at a higher rate than the service rate of the queue, then the queue size will grow. If the queue space is finite then, in addition to the delay experienced by the packets until service, losses will also occur. Observe that congestion is not a static resource shortage problem, but rather a dynamic resource allocation problem. Networks need to serve all users requests, which may be unpredictable and bursty in their behaviour (starting time, bit rate, and duration). However network resources are finite, and must be managed for sharing among the competing users.

## II. LITERATURE REVIEW ( PREVIOUS WORKS )

There are many existing congestion control schemes. Congestion that is caused by a shortage of buffer space can be solved by increasing the amount of buffers; Congestion caused by slow links could be solved by speeding-up the links; while congestion caused by slow processors could be solved by increasing the processor speed. According to Nagle (1987),there is the hope thatif not one, the solutions to all of the above will cause the congestion problem to go away. However, congestion cannot be solved by increasing the buffer size only postpones the inevitable packet loss when network load is larger than the increased network capacity.

In 1990, Jain described two main classes of congestion control schemes: 1. R*esource creation* schemes, which dynamically increase the capacity of the resource, and 2. D*emand reduction* schemes, which reduce the demand on the resource. For Internet networks, the bandwidth on each link is generally static; therefore, resource creation schemes could not be progressive in congestion management..This is becausecongestion is not a static resource shortage problem, but a dynamic allocation problem. Demand reduction schemes was then appluaded. It was subdivided into three subclasses:

- *Service denial* schemes do not allow further resource allocation. Connection-oriented networks, for example, can prevent new connections from being formed.

- *Service degradation* schemes ask all users (existing as well as new) to reduce their loads.
- *Scheduling* schemes ask users to schedule their demands so that the total demand is less than the capacity. This subclass is a special instance of the service degradation subclass.

Also, several alternatives has been proposed for the location of congestion control, such as in the Transport Layer, Network Layer, Data Link Layer, and in specific network entrances, such as routers.

Fuzzy Logic Control can be considered as suitable candidate for AQM-based control mechanism due to its reported strength in controlling nonlinear systems using linguistic information. The capability to qualitatively capture the attributes of a control system based on observable phenomena is a main feature of fuzzy logic control and has been demonstrated in various places in the research literature as well as in commercial products. The main idea is that if the fuzzy logic control is designed with a good (intuitive) understanding of the system to be controlled, the limitations due to the complexity system's parameters introduced on a mathematical model can be avoided.

The application of fuzzy control techniques to the problem of congestion control in TCP/IP networks is worthy of investigation. This approach avoids the difficulties associated in obtaining a precise enough mathematical model (amicable to analysis) in using conventional analytical methods. This is made possible because there are some intuitive understandings of congestion control. The purpose of this paper is summarized thus:

1. To design a technique of managing the available static network resources in order to meet up with the infinite dynamic demands from users and uses.
2. To reduce the rate of source transmissions to that which can be sustained by the network, thus preventing loss of data due to congestion.
3. To formulate an effective, robust, and internet network congestion control methodology, using fuzzy logic controllers.

## III. FUZZY LOGIC CONGESTION CONTROLLER

- As stated earlier, Fuzzy Logic Congestion Control approach could be seen as an alternative way of designing feedback controllers. Though non-conventional, it is applicable wherever it is convenient and effective to build a control algorithm without relying on formal models of the controlled system and control theoretic tools.
- Fuzzy Logic Control defines a nonlinear control law by employing a set of fuzzy "IF-THEN" rules. The "IF" part describes the fuzzy inputs and the "THEN" part of a fuzzy rule specifies a control action (law) applicable within the fuzzy region from the "IF" part.

Here ***the control algorithm*** is formulated as a set of commonsense rules.

### 3.1 Fuzzy logic controlled system model

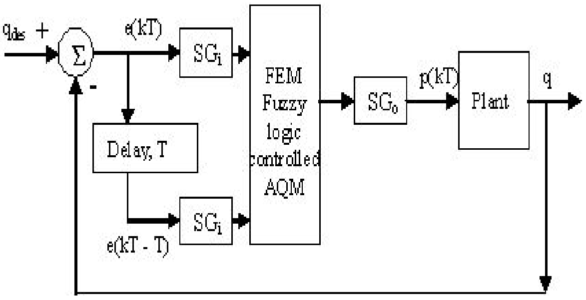


Fig.1. FLC system model

The system model of is shown above. Here, all quantities are considered at the discrete instant *kT*, with

- *T* the sampling period;
- *e(kT) = qdes – q* is the error on the controlled variable queue length, *q*, at each sampling period;
- *e(kT – T)* is the error of queue length with a delay *T* (at the previous sampling period);
- *p(kT)* is the *mark* probability;
- *SGi* and *SGo* are scaling gains.

### 3.2 RULE BASE DESIGN

- Multiple inputs are used to capture the dynamic state of the controlled system more accurately, and also to offer better ability to linguistically describe the system dynamics. In this paper, we utilize a two-input, single-output fuzzy controller on the buffer of each output port of a router in TCP/IP networks. Obvious information to the controller, the queue length is considered as an input, as it can give a clear view of the local congestion status at a given time, like the level of queuing delay.
- Two input linguistic variables are used: the "queue length", and the "rate of change of queue".
- ✓ The linguistic variable "queue length" is composed of three linguistic values: "empty", "moderate" and "full".
- ✓ The linguistic variable "rate of change of queue" is composed of three linguistic values: "decreasing", "zero" and "increasing".
- One output linguistic variable is used: the "drop probability", which is composed of four linguistic values: "zero", "low", "medium" and "high"

Membership functions of the linguistic values representing the linguistic variables of the fuzzy system used as an example.

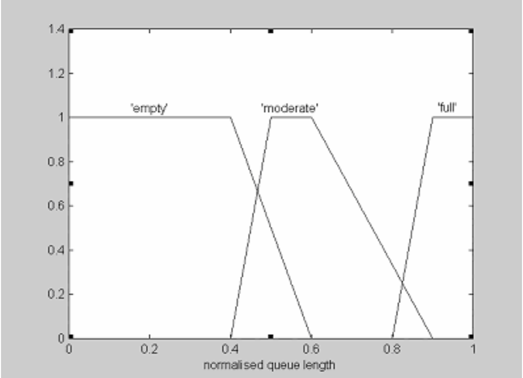


Fig.2. Membership functions of the linguistic values representing the linguistic variables of the fuzzy system used as an example.

The rule base of such a fuzzy system can be constructed by the following example rules:
Rule 1: if queue is empty then drop probability is zero
Rule 2: if queue is moderate and rate of change of queue is decreasing then drop probability is zero
Rule 3: if queue is moderate and rate of change of queue is zero then drop probability is low
Rule 4: if queue is moderate and rate of change of queue is increasing then drop probability is medium.
Rule 5: if queue is full and rate of change of queue is decreasing then drop probability is medium.
Rule 6: if queue is full and rate of change of queue is zero then drop probability is high
Rule 7: if queue is full and rate of change of queue is increasing then drop probability is high.

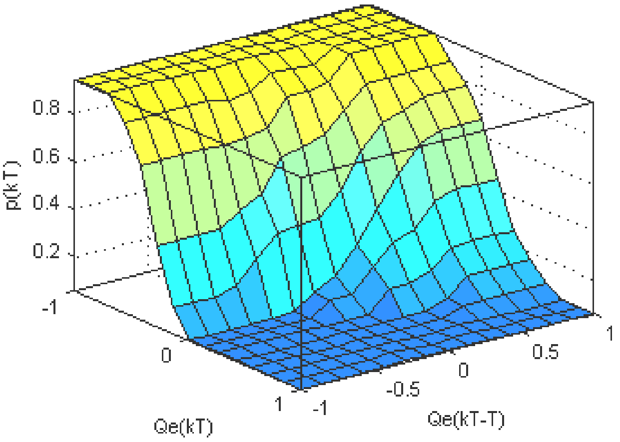


Fig.2. Decision surface of the fuzzy inference engine (the control surface is shaped by the rule base and the linguistic values of the linguistic variables)

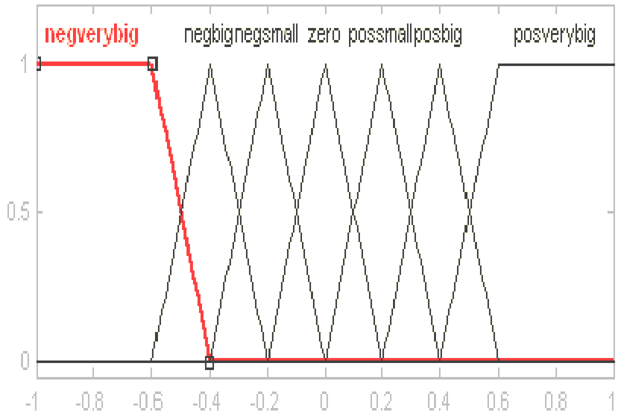


Fig.3. Membership functions of the linguistic values.

## IV. SIMULATIVE EVALUATION

In this work, we use fuzzy logic techniques to develop a new AQM scheme, implemented within the Diff-Serv framework - using a two-class FEM controller (FEM In/Out – FIO) - to provide congestion control. The Fuzzy Explicit Marking (FEM) controller was proposed recently to provide congestion control in TCP/IP best-effort networks. The proposed fuzzy control system is designed to regulate the queues of IP routers at a predefined level, by achieving a specified target queue length (TQL), in order to maintain both high utilization and low mean delay. A fuzzy inference engine (FIE) is designed to operate on router buffer queues, and uses linguistic rules to mark packets in TCP/IP networks.

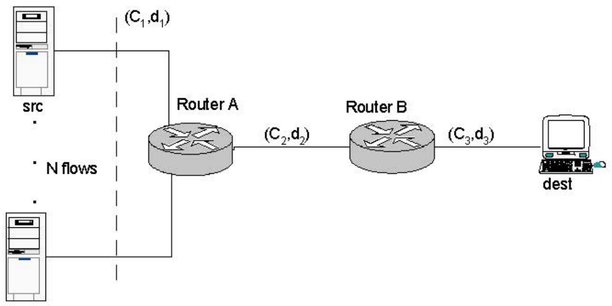


Fig.3. Fuzzy Logic Control Network topology.

At this juncture, we evaluate the performance and robustness of the proposed fuzzy logic based scheme, Fuzzy Explicit Marking In/Out, (FIO) controller in comparison with Random Early Detection In/Out (RIO) using a recent version of NS-2 simulator. We have conducted a series of simulations in order to evaluate the performance of both FIO and RIO schemes, and examine their capabilities to provide the necessary Quality of Service, (QoS) .

Here the performances (i.e. Quality of Service metrics) are:

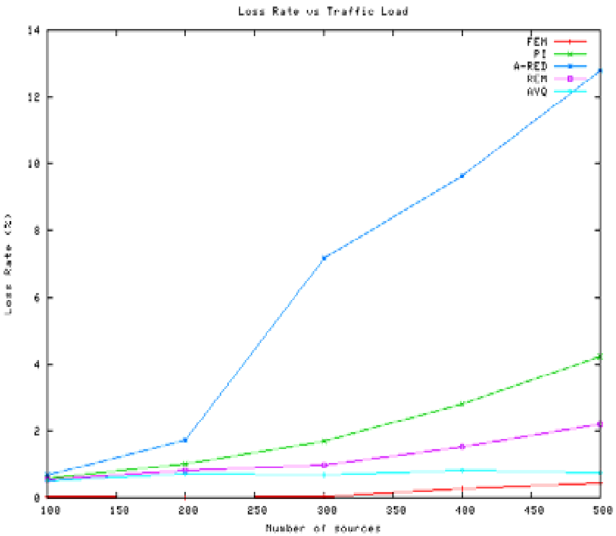
1. Bottleneck link utilization,
2. Loss rate
3. Mean queuing delay with its standard deviation.

**Simulation Parameter**

The sampling period for FIO AQM is fixed to 0.006sec. The TQL for best-effort traffic is set to 100 packets; the TQL for assured traffic is set to 200 packets, buffer size of 500 packets. For RIO, the minimum and maximum thresholds, for best-effort traffic, are set to 50 and 150 packets, respectively. The equivalent values for assured traffic are 100 and 300 packets, respectively. The maximum mark probability for best-efforts traffic is set to 0.1, whereas the one for assured traffic is set to 0.02, for both FIO and RIO. The link capacities and propagation delays are set as follows: (*C1*, *d1*) = (100Mbps, 5ms), (*C2*, *d2*) = (15Mbps, 120ms), and (*C3*, *d3*) = (200Mbps, 5ms), while $N = 100$. The simulation time is *100 sec*.

**Effect of the traffic load factor, *N* on packet loss:**

Here we study the effect of the traffic load factor, *N* when bottleneck propagation delay is *120ms*, the queue length depicted as d. As traffic load factors increase from 100 to 200; 300; 400; and 500 flows respectively, we observe that the loss rate increases. FEM shows stable and low packet loss over large traffic load. A-RED has the largest drops with a large increase of packet loss with respect to higher loads.



Loss Rate vs Traffic Load (for 100-500 flows)

## V. CONCLUSIONS AND RECOMMENDATIONS

In conclusion, there is a real challenge in the control of congestion in communication networks, especially the ones supporting video, voice and data applications simultaneously. Computational Intelligence techniques are expected to play a central role, especially in the large scale, geographically distributed network systems. Hybrids are also expected to supplement these techniques and prove useful, especially in optimizing the overall network objectives.

## REFERENCES

[1] V. Jacobson, "Congestion Avoidance and Control" *ACM Computer Communication Review; Proceedings of the Sigcomm '88 Symposium in Stanford, CA, August, 1988*, vol. 18, pp. 314-329, 1988.
[2] Mamdani, E.H. (1974). Applications of fuzzy algorithms for simple dynamic 121*(12)*, 1585-1588.
[3] C. H. Papadimitriou and J. N. Tsitsiklis, The complexity of Optimal Queueing network control, to appear in Mathematics of Operations Research. (Available to download at http://lids.mit.edu/~jnt/exprev.ps).
[4] A. Pitsillides, A. Sekercioglu, Intelligent Congestion Control Framework for Integrated Services Communication Networks, TR-99-1, Technical Report, Dep. of Computer Science, University of Cyprus, January 1999.
[5] Braden et al, Recommendations on Queue Management and Congestion Avoidance in the Internet, RFC2309, April 1998.
[6] K.K. Ramakrishnan, and S. Floyd, A proposal to add explicit congestion notification (ECN) to IP, draft-kksjf-ecn-03.txt, October 1998. (RFC2481, January 1999).
[7] Hadi Salim, Internet draft-salim-jhsbnns-ecn-00.txt, A proposal for Backward ECN for the Internet Protocol (IPv4/IPv6), June 1998.
[8] ATM Forum, Traffic management specification version 4.0, Tech. Rep. AF-TM-0056.000, April 1996.
[9] W. Stevens, "TCP Slow Start, Congestion Avoidance, Fast Retransmit, and Fast Recovery Algorithms", RFC 2001, January 1997.
[10] G. M. Woodruff, et al "A congestion control framework for high speed integrated packetized transport", GLOBECOM'88.