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# Design and comparison of a fuzzy logic controller for Active Queue Control

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**Abstract:** - Network blockage administration is a complicated hindrance which needs quick to recover, maybe swift, and control schemes to acquire adequate working. Designing equipped blockage handling schemes for set of connections for computers is identified to be hard due to the difficulty of obtaining realistic, fine analytical models. It becomes really difficult to apply the conventional control methodology; that depend on the obtain-ability of these models. It has been reported that effective solutions for certain classes of control problems may be achieved by employing an Intelligent Fuzzy Logic Control methodology. Being specifically suitable for complex and non-linear systems; when it becomes difficult to obtain an analytical model, on the contrary it is made possible to capture the understanding of their behavior by linguistic models. As a result, many of the researchers have used fuzzy logic to devise efficient techniques for congestion control.

**Keywords:** Fuzzy Logic Controller for Active Queue Control

## 1. INTRODUCTION

Till today there is no Universally recognized and acceptable solution for congestion control; creating room for researchers to propose new approaches; though the cosmic research attempts have been made since last few decades and there is a large number of different proposed control schemes (Kulatunga. 2013). (Hussein, 2015), (Bedi. 2015). (Nichols and Jacobson, 2012). These solutions cannot cop up with recent needs of the networks; and so are becoming ineffective, yet making network congestion unmanageable unless efficient approaches for congestion control are not developed (Staff, 2012) (Nichols and Van, 2013). (Kuhn *et al.*, 2014). Consequent upon the above reasoning we propose an intelligent fuzzy logic control methodology for designing such a complex control system that can be applied for TCP/IP networks to control blockage.

## 2. CONGESTION CONTROL

Since many decades the blockage methods have been extensively discussed and studied that have been employed by the TCP/IP protocol. Apparently [8] the offered TCP congestion avoidance mechanisms, are not adequate to impart good service in all situations, although being essential and dominant. As a result, AQM systems have been set out to facilitate and manage the blockage.

It became possible with the advent of AQM to split the policies of for demonstrating blockage from the policies of dropping packets at the router level. The AQM systems begins packet dropping in advance with the aim of being capable to alert traffic origins about the just beginning stages of blockage. For higher network utilization as well as small delay and low packet loss numerous AQM methods have been presented; in the TCP/IP best-effort networks by means of adjusting queues at the traffic jam connections, few of which are random early detection (RED) (Rai, 2016) proportional-integral (PI) controller (Kala. 2014) and CoDel (Control Delay) (Nichols and Van, 2013). (Tanvi, 2014)

Still, these AQM systems need a systematic arrangement of control factors. These methods are unable to cop up with the dynamic network changes, and so, they present larger delays, and large buffer variations, and accordingly are not capable of successfully controlling the queues at router level.

## 3. FUZZY LOGIC BASED CONGESTION CONTROL

When it becomes difficult to obtain formal analytical model, due to which strict control theoretic methods cannot be used, then Fuzzy Logic Control (FLC) may be the possible method of designing feedback controllers (Berlanga, *et al.*, 2010). (Nojima, *et al.*, 2010). Linguist rules are summarized in a set to identify a control law which is non-linear. If the available model is excessively complex and very much nonlinear in such situations FLC is successfully applied (Mercy *et al.*, 2010). (Mencar, *et al.*, 2011).

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Besides, it provides effective blockage control over a wide range of networking technologies; fuzzy logic is freshly put in to TCP/IP best-effort networks (Kaur, and Kaur 2012). (Suhas *et al.*, 2013) (Bazaz 2013). (Jungang and Yang, 2013).

## 4. CONGESTION CONTROL ALGORITHMS

Being the latest AQM controller the CoDel is the controller which is specifically designed to control the delay. CoDel: intends to offer fragment of the buffer-bloat way out, suggesting a modern tactic to AQM appropriate for today's Internet called CoDel. This is a "no- buttons" AQM that adjusts to varying link paces (Nichols and Van, 2013). (Tanvi, 2014)

FAQM: The controller which deals with uncertainties and nonlinearities in a superior manner is a fuzzy logic-based controller; planned to function in TCP/IP best-effort networks with long lived traffic, and particularly at the buffer available at output port in the IP routers'. The proposed FAQM is an AQM methodology to present an advanced and more knowable, inherently strong blockage method realization in networks within TCP/IP environments (Jilani,2015). (Singhala. and Shah.2014).

## 5. METHODOLOGY

The number of inputs used in our designed system is two with one out put making it a multiple input single output system (MISO) the fuzzy inference system used is Mamdani inference system; which is the default system available in the fuzzy logic tool box of the MATLAB as shown in **(Fig: 1)**.

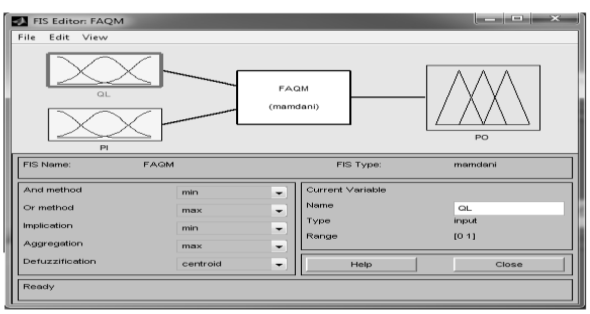


**Fig. 1. the Fuzzy inference system of the proposed system**

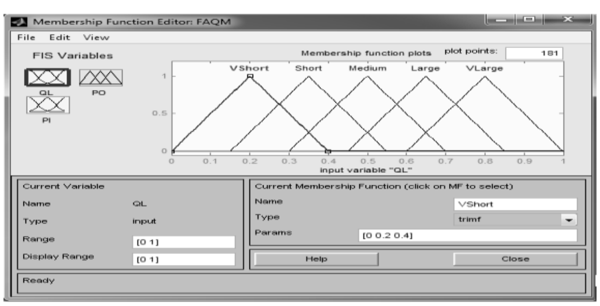


**Fig. 2. QL membership function**

The variables used for input are queue length (QL) and probability input (PI) as shown in **(Fig.2)**; while the variable used for output is probability out (PO) and membership function used is triangular for input as well as output.**(Fig. 3)** is showing graphical representation of the input and output relationship in the form of the rule viewer, while overall behavior of the system is shown below in **(Fig: 4)**, with the help of surface viewer.

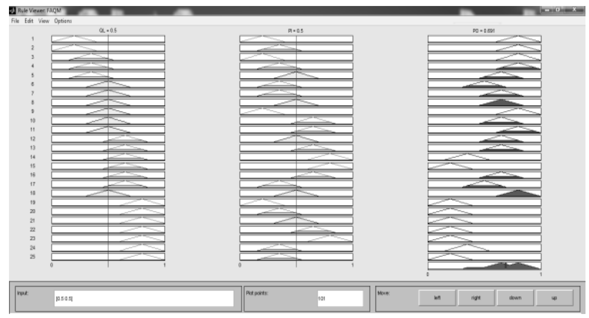

**Fig. 3. The Rule Viewer of the system**

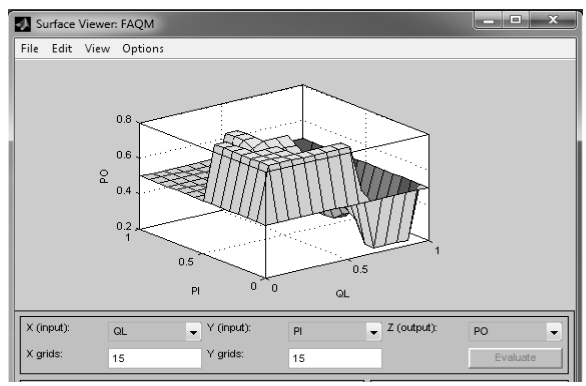


**Fig. 4. The overall behavior of the system**

This designed system in MATLAB is interfaced with the renowned simulation tool NS-2 using fuzzy logic library of C++ along with activating the queue class in the plant of the system; from where the simulations for comparison of the designed system with the recently developed AQM controller CoDel are obtain.

## 6. SIMULATION METHODOLOGY

The two control methodologies discussed earlier are assessed with through an interface to NS2. By the appropriate processing of output data improved statistical significance of the results are being achieved. The results are obtained using the latest version of the NS2 simulator. The framework provides three main metrics number of FTP connections, Bandwidth, and Queue delays. The generated outputs are: Arrival, Departure, drop, and Queue utilization, along with this Round Trip Time (delay) is also provided using statistical mean / average.

## 7. NETWORK SCENARIOS

A blend of traffic mix and a topology of network is known as a network scenario. The traffic is of long lived TCP flows (e.g. FTP transfers of large files). The long-lived TCP flows are active at all times during the simulation. Thetopology denotes a network composed of a single link which is congested with one-way traffic. The framework allows different roundtrip times (RTT) for each traffic flow.

## 8. PARAMETERS SETTINGS FOR FUZZY LOGIC CONTROLLER

The existing queue regulation algorithm CoDel and the proposed fuzzy logic controller FAQM are constituted to possess the queue size at the uppermost level in terms of number of packets is set to 800 packets, the TCP window can accommodate a maximum of 50 packets; and the size of the packet is set as 500 Bytes. The input parameters are Bandwidth, Link delay and number of FTP's, while performance evaluation is based on the major output factors such as, Arrival of Packets, Departure of Packets, number of Packets Dropped, and Queue utilization. To further strengthen the validation process another factor RTT (round trip time) is used to evaluate the performance.

## 9. PERFORMANCE COMPARISON OF FUZZY LOGIC CONTROLLER (FAQM)

Here the working of FAQM the proposed Algorithm is compared and validated. For comparison a latest Active Queue adjustment controller CoDel is Chosen. The parameters that put a vital impact on performance and are used for comparison, are throughput (packet departure) packet drop, and queue utilization.

**Table: 1. Scenario-1**

| ftp 100 bandwidth 2MB link delay 10ms (Scenario 1) | | | | | |
|---|---|---|---|---|---|
| **Controller** | **Arrival** | **Departure** | **Drop** | **Average Queue** | **Throughput in %** |
| **FAQM** | **639745** | **575051** | **64473** | **202** | **90%** |
| **CoDel** | **708799** | **575016** | **133751** | **40.14** | **82.04** |

Scenario-1**(Table-1)** is set as a starting point for comparing the proposed/designed FAQM controller with the recently developed AQM controller CoDel. In this situation FAQM the proposed controller is working superiorly than CoDel for all the evaluation parameters like throughput, packet drop and queue utilization which is shown if **(Fig. 5-6)**. The calculated percentage of throughput also validates the above statement.

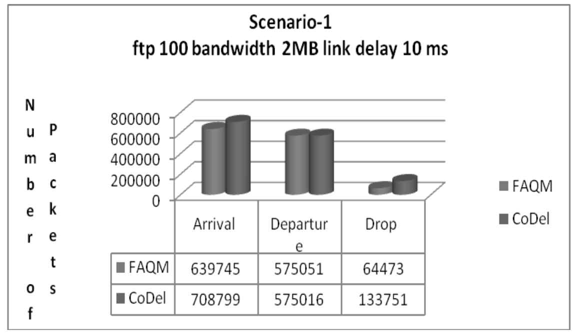


**Fig: 5. Arrival, Departure, and Drop for scenario-1**

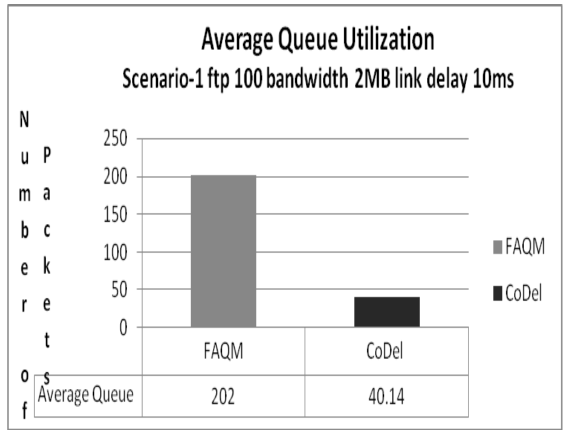


**Fig: 6. Queue utilization for scenario-1**

The remaining sets of simulations are performed by varying the input parameters like number of ftp, bandwidth, and link delay to check behavior of the proposed FAQM controller in different state of affairs compared to the CoDel.

**Table: 2. Scenario-2**

| ftp 400 bandwidth 2MB link delay 10ms (Scenario 2) | | | | | |
|---|---|---|---|---|---|
| **Controller** | **Arrival** | **Departure** | **Drop** | **Average Queue** | **Throughput in %** |
| **FAQM** | **745677** | **575079** | **170577** | **150.74** | **77.12%** |
| **CoDel** | **781079** | **575352** | **205669** | **74** | **73.66%** |

The impact of increase in number of ftp connections **(Table-2)** is quite considerable on the throughput of both the controllers which is fairly decreased; on the other hand still the throughput of the FAQM is quite better than the CoDel. The number of packets dropped is increased very largely; yet the number of packets dropped for FAQM is smaller than the CoDel. Average queue utilization for the FAQM is decreased though it is better than the CoDel.

**Table: 3. Scenario-3**

| ftp 100 bandwidth 2MB link delay 20ms (Scenario 3) | | | | | |
|---|---|---|---|---|---|
| **Controller** | **Arrival** | **Departure** | **Drop** | **Average Queue** | **Throughput in %** |
| **FAQM** | **639303** | **574998** | **64116** | **163** | **90%** |
| **CoDel** | **696651** | **574983** | **121647** | **40** | **82.53%** |

Increase in link delay is the constituting parameter of this scenario as shown in **(Table: 3)**. The CoDel controller is specifically designed to manage delays; so its performance is improved compared to last scenario, although the performance of FAQM is better than the CoDel in all evaluation parameters like throughput, packet drop, and queue utilization.

**Table: 4. Scenario-4**

| ftp 100 bandwidth 6MB link delay 10ms (Scenario 4) | | | | | |
|---|---|---|---|---|---|
| **Controller** | **Arrival** | **Departure** | **Drop** | **Average Queue** | **Throughput in %** |
| **FAQM25** | **1916474** | **1724353** | **192068** | **44.38** | **90%** |
| **CoDel** | **1946704** | **1702653** | **243869** | **91.84** | **87.46%** |

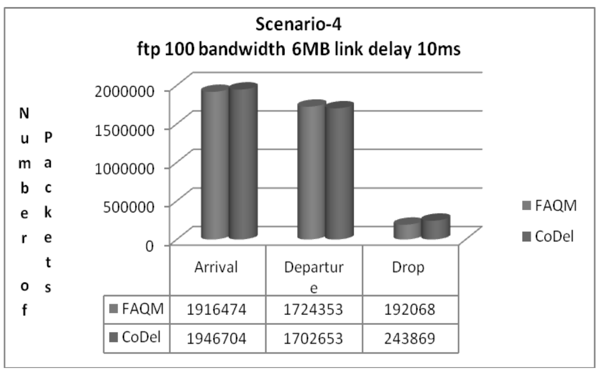


**Fig: 7. Arrival, Departure, and Drop for scenario-4**

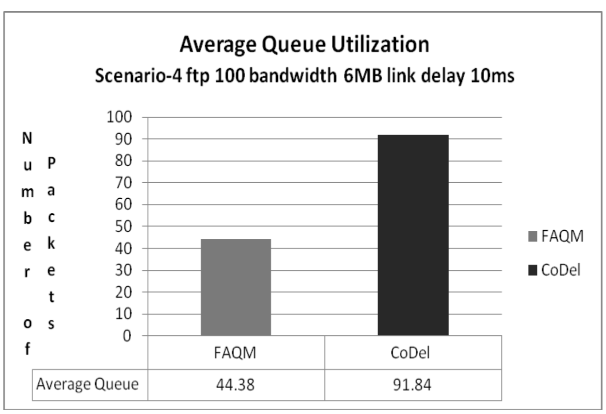


**Fig: 8. Queue utilization for scenario-4**

The last phase of simulation is bandwidth variation as shown in **(Table: 4)**; where number of ftp's and link delay is kept constant while bandwidth is increased the throughput, and packet drop of FAQM is far better than the CoDel; while the queue utilization of the FAQM is decreased as compared with the CoDel as shown in **(Fig. 7-8)**. The queue utilization is directly proportional to the round trip time; so in current state of affairs the round trip time of the FAQM controller is smaller than the CoDel, this further strengthens and validates the performance of the designed FAQM controller as shown in **(Fig. 9)**.

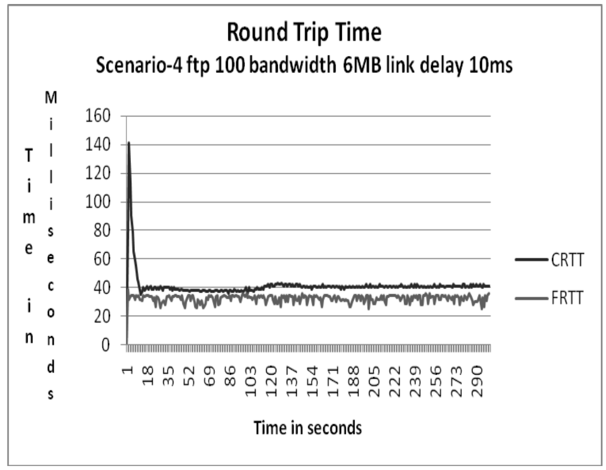


**Fig: 9. Comparison of Round Trip Time for CoDel and the proposed FAQM controller**

## 10. CONCLUSION

Active Queue adjustment algorithms are the basic system to achieve network congestion control. The present day Active Queue control schemes for TCP/IP networks are unable to meet the needs of the group of people using internet. In this paper a fresh active queue adjustment algorithm called FAQM is proposed based on fuzzy logic.

With the clear linguistic understanding of the system behavior; simple fuzzy knowledge base is used in the design procedure. To effectively use the strength of fuzzy logic, the limitations of the previously applied AQM controllers in TCP/IP networks are addressed; the detailed power of fuzzy logic is effectively used. The results derived from the simulations clearly show that FAQM controller presents the required characteristics; such as swift system response along with better behavior in the form of throughput, queue usage, and loss of packets, in addition to this, it exhibits consistent response during the variations in queues and waits (delays or RTT). The recommended FAQM controller is adjustable to the vastly uncertain and variable nature of the networks. The presented results grow confidence that major improvement on controlling the congestion in TCP/IP environments can be attained with the fuzzy control methodology.

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