Fuzzy Based Routing Algorithm for Congestion Control in Internet

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***Abstract*— In this paper we propose a fuzzy based routing algorithm in which the link cost are dynamically assigned using a fuzzy system. Based on a set of fuzzy rules, link cost is dynamically assigned depending upon the current condition of the network. The proposed fuzzy scheme determines the integrity of a link given the current congestion state calculated via the delay experienced in the network and the offered load on the network. Delay and Queue length are the two inputs to the Fuzzy system. Delay was estimated by the time taken for the packets to travel between nodes and queue length is the number of packets waiting in the queue. The cost of a link for certain interval is the output of the fuzzy system. Simulations results showed that the fuzzy scheme offered improved performance in congestion avoidance.**

Keywords- Link Cost, QM, Network Routing, Congestion Control, FL

I. INTRODUCTION

Congestion is the condition of sustained network overload where the demand for network resources is close to or exceeds capacity. Network resources, namely link bandwidth and buffer space in the routers, are both finite and in many cases still expensive. Routing is the one of the major components of the network control techniques that determines the overall network performance in terms of quality and quantity of delivered service. A good routing algorithm redirects traffic over less congested routes of the network and ensures the coordination between all the nodes. The result of good quality routing algorithm is to increase throughput for the average delay per packet under high load conditions and to decrease average delay per packet under low and moderate load condition. Congestion will occur if the resources are not managed efficiently. Congestion is a complex problem to define. It is felt by a degradation of performance.

A moment ago, several QM schemes have been proposed to provide high network utilization with low loss and delay by regulating queues at the bottleneck links in TCP/IP, including random early detection (RED) [2], Random Exponential Marking (REM) [3]. Contrary to the Tail Drop(TD), QM mechanism[4] start dropping packets earlier in order to be able to notify traffic sources about the incipient stages of congestion.

In this paper, we propose an active queue management algorithm making use of a Fuzzy system. A requirement for any queue management scheme for congestion is congestion detection. This was implemented in the simplest form by a static threshold in queue length, although more elaborate weighted moving averages or link utilization have been proposed. In our scheme, we make use of a fuzzy system to ascertain the level of congestion on the link.

On detecting that the link cost exceeds a certain threshold, the router sets a bit in the packet header (CE bit) as a part of the ECN feedback scheme. The receiver copies this bit into the header of the acknowledgment packet, and the flow control mechanism at the sender is responsible for adjusting the window (or rate) based on a certain algorithm. The algorithms used for congestion detection and window adjustment as responses to explicit feedback are part of the queue management and flow control mechanisms, respectively.

A. QM Mechanism

AQM is a solution for detecting incoming congestion early and delivering the congestion notification to the source, so that the source can decrease the sending rate to avoid possible buffer overflow. QM mechanism intends to provide high link utilization with low failure rate and queuing delay, while responding speedily to load changes. RED [2] was the first QM algorithm proposed that detects congestion and measures the traffic load using average queue size.

Suter [5] studied the throughput of RED. It is found that with large number of TCP connections, the throughput of RED is generally low. RED has a number of problems such as low throughput, large delay and inducing instability in networks. Previous enhancements to RED attempted to improve the performance of RED by modifying the parameters of RED. However such modifications result in limited improvement.

B. Routing Metrics

Routing metrics are metrics used by a router to make routing decision. Router metrics can hold any numeral of values that help the router find out the finest route among several routes to a destination. A router metric usually based on information like queue size, bandwidth, load, hop count, path cost and delay. The choice of the routing metrics significantly affects the performance parameters of the routing algorithm like throughput and average packet delay. Queue size defines the buffer capacity at the node and it refers to the number of packets waiting to get processed. Delay gives a fairly good estimate of the congestion in the network but it is very difficult to distinguish between delays caused because of selection of longer routes by the packets or because of the congestion in the network. Maximum Transmission Unit (MTU) or transmission capacity of a link is also a major routing metric. In our simulations, we have allocated buffer capacity for each link. The length of the output queue is also one of the factor that affect the packet's delay.

In this work, we propose to build up a fuzzy system based routing algorithm, which is suitable under all load conditions. This idea achieves performance close or equal to that achievable by using a set of optimally weighted metrics for a particular load conditions. By doing this we maximize the throughput of the network and achieve high utilization.

II. FUZZY SYSTEM

Fuzzy Logic was an approach of processing data by allowing fractional set membership rather than crisp set membership or non- membership. FL provides a simple technique to arrive at an exact conclusion based upon unclear, ambiguous, imprecise, noisy, or missing input information. FL's approach to manage problems, mimic how a person would build decisions much faster. A Fuzzy system is a rule-based system that uses fuzzy logic, rather than Boolean logic [6]. A fuzzy system is characterized by the inference system that contains the rule base for the system, input membership functions that are used for fuzzification of the input variables and de-fuzzification of the output variables.

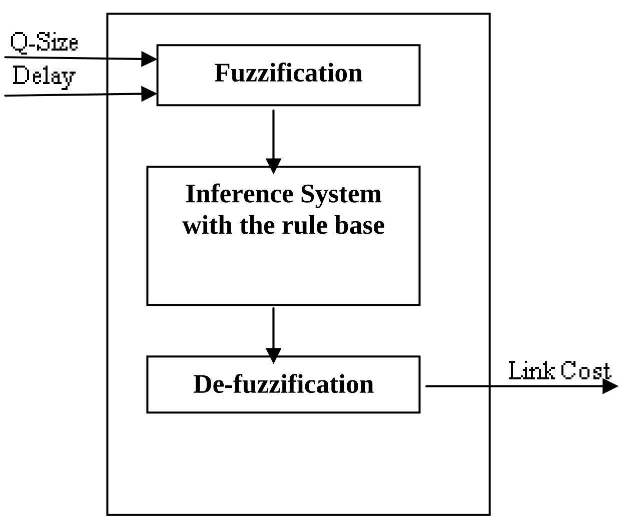

Figure 1 Block diagram of Fuzzy System

Fuzzification translates crisp inputs into fuzzy values. The inference engine calculates the fuzzy output using fuzzy rules which are linguistic in the form of IF-THEN rules. Q-size and delay are the routing metrics used in the proposed fuzzy system. These metrics are measured at each node of the network for each link and are given as input parameters to the fuzzy system. Link cost is computed by the fuzzy system as the output.

In the proposed fuzzy system, Mamdani minimum inference method [7] where the "and" operation was set to minimum was used as the fuzzy inference method. De- fuzzication was carried out using height defuzzification.

Rule Base for fuzzy inference system is illustrated in Table 1.

Fuzzy Rules		
Q-size	**delay**	**cost**
VS	VS	VS
VS	S	VS
VS	M	S
VS	L	S
VS	VL	M
S	VS	VS
S	S	S
S	M	S
S	L	M
S	VL	M
M	VS	S
M	S	S
M	M	M
M	L	M
M	VL	L
L	VS	S
L	S	M
L	M	M
L	L	L
L	VL	L
VL	VS	VL
VL	S	VL
VL	M	VL
Vl	L	VL
VL	VL	VL

Table 1: Rule Base for fuzzy Based routing Algorithm

In the form of IF-THEN:

"If Q-size verysmall and delay verysmall then cost verysmall"
"If Q-size verysmall and delay small then cost verysmall"

A. Membership Functions

The membership function is a graphical representation of the magnitude of participation of each input. The rules use the input membership values as weighting factors to determine their influence on the fuzzy output sets of the final output conclusion.

Triangular membership function were used for the linguistic variables that represent Q-size, delay and cost link.

The range of Q size membership function is 1 to 5

QS Range Value			
QSIZE	range[0]	range[1]	range[2]
VS	1	1.5	2
S	1.5	2	2.5
M	2	2.5	3
L	2.5	3	3.5
VL	3	4	5

Table 2: QS Rule Set

The range of delay membership function 0 to .24

Dl Range Value			
DELAY	range[0]	range[1]	range[2]
VS	-0.058	-0.043	0.05
S	-0.043	0.05	0.1
M	0.05	0.1	0.15
L	0.15	0.2	0.24
VL	0.2	0.24	0.29

Table 3: Dl Rule Set

The range of link cost membership function is 1 to 1.5

LC Range Value			
LINK COST	range[0]	range[1]	range[2]
VS	0.8	1	1.05
S	1	1.05	1.25
M	1.1	1.25	1.35
L	1.25	1.35	1.5
VL	1.4	1.5	1.625

Table 4: LC Rule Set

B. Notations

Following variables are used to define and evaluate the performance of our proposed algorithm:

VS: Very Small
S: Small
M:Medium
L:Large
VL: Very Large
X: both expected inputs of QS and Dl of our network.
M1: value return for QS from Figure 2.

Rule For Input parameters: QS(m1) and Dl(m2)
To check input value is in range or not

```
if ((x<range[0] )||(x>range[2])) return 0;

if ((x>= range[0]) &&(x<= range[1]))
 return
 ((x-range[0])/(range[1]-range[0]));

if((x>= range[1])&& (x<= range[2]))
return((range[2]-x)/(range[1]-range[0]));

ELSE return 0;
```

Figure2. Validate input parameter

C. Fuzzy Based Algorithm

1. QS and Dl: input parameters
2. IF QS>5
   QS=4.95
3. IF QS=1
   QS=1.002
4. IF dl>=0.24
   Dl=0.235
5. M1, M2, lc: integer variable
6. Height, Peak: Array Variable
7. Execute step 8 to step 13 for all fuzzy rules in table 1.
8. Get the QS range for the fuzzy rule selected from table 2.
9. Get the Dl range for the fuzzy rule selected from Table 3.
10. Get the Cost range for the fuzzy rule selected from Table 4.
11. Calculate M1 and M2 from Figure 2.
12. IF M1>M2 then Height=M2
    else
    Height=M1
13. Peak= range[1] in Table 4.
14. LC=(Sum((Height1*Peak1)….(Height25*Peak25)))/Sum(Height1…Height25)
15. IF (1.3 < LC < 1.65)
    packet transfer continues
    else
    Packet drop.

III. SYSYEM SETUP

The network topology used is shown in figure 3. Figure 3 consists of 14 nodes and 21 Bi- directional links. Each and every link in both the network had an associated buffer space called queue size. Queue size and delay are the two routing parameters used for calculating present link cost. The bandwidth in both networks for each link was set to 1.5 MBPS. Propagation delay and Queue size were set as per Table 3 and Table 2. All the simulations are carried out on Network Simulator [12].

IV. RESULTS AND ANALYSIS

As per simulation results obtained, the throughput of the network increases when delay and queue size are used as metric. On the basis of load conditions queue size was able to divert the traffic from a congested link to a link which had a spare capacity efficiently. But because of the composite metric of delay and queue size, we observed that the throughput obtained was better. Also with increasing the queue size, the composite metric's throughput was higher.
Among all the combinations we have tried 2.5, 0.24 and 3, 0.24 for queue size and delay respectively gave better performance.
Our simulation results discovered a great improvement in performance measures with the proposed fuzzy based routing algorithm.

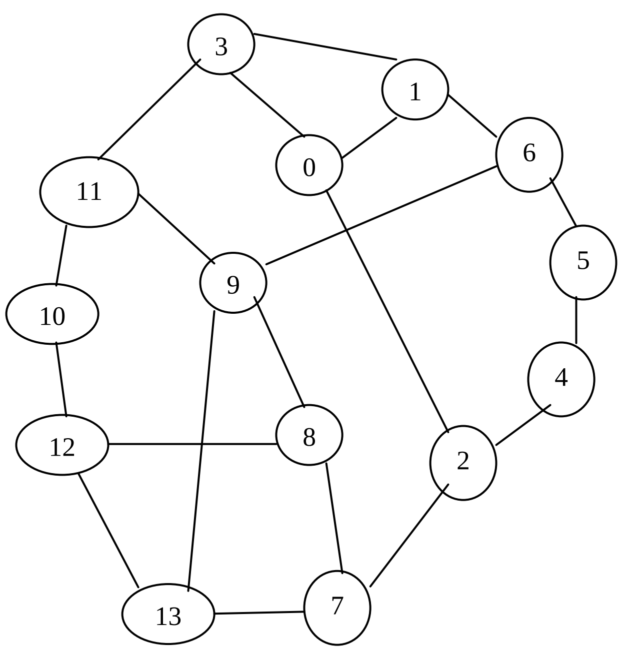

Figure3. Numbers within the circles are node identifiers. Each edge represents a bi-directional link.

Event	Time	From node	To node	Pkt type	Pkt size	Flags	Fid	Src addr	Dst addr	Seq num	Pkt id

Figure4. Fields appearing in a trace

Event	Time	From Node	To Node	Pkt type	Pkt size	Src address	Dest Address	Seq no	Pkt Id
+	.1	0	2	tcp	40	0	13	0	0
_	.1	0	2	tcp	40	0	13	0	0
r	.34	0	2	tcp	40	0	13	0	0
+	.34	2	7	tcp	40	0	13	0	0
_	.34	2	7	tcp	40	0	13	0	0
r	.58	2	7	tcp	40	0	13	0	0
+	.58	7	13	tcp	40	0	13	0	0
_	.58	7	13	tcp	40	0	13	0	0
r	.82	7	13	tcp	40	0	13	0	0
+	.82	13	7	ack	40	13	0	0	1
_	.82	13	7	ack	40	13	0	0	1
r	1.06	13	7	ack	40	13	0	0	1
+	1.06	7	2	ack	40	13	0	0	1
_	1.06	7	2	ack	40	13	0	0	1
r	1.30	7	2	ack	40	13	0	0	1
+	1.30	2	0	ack	40	13	0	0	1
_	1.30	2	0	ack	40	13	0	0	1
r	1.54	2	0	ack	40	13	0	0	1
+	1.54	0	2	tcp	40	0	13	1	2
-	1.54	0	2	tcp	40	0	13	1	2
r	1.54	0	2	tcp	40	0	13	1	3

Table 5: Simulation results when QS=2.5 and Dl=0.24. No packet drop.

Event	Time	From Node	To Node	Pkt Type	Pkt size	Src adr	Dest adr	Seq no	Pkt Id
+	0.1	0	2	tcp	40	0	13	0	0
d	0.1	0	2	tcp	40	0	13	0	0
+	3.1	0	2	tcp	40	0	13	0	1
d	3.1	0	2	tcp	40	0	13	0	1

Table 6: Simulation results when QS=1.5 and Dl=0.2. Max packet drop.

V. CONCLUSION AND FUTURE WORK

The proposed fuzzy based algorithm showed better utilization of network resources and system performance because of the composite metric of queue size and delay. Fuzzy system was able to match the top performance of the composite metric under different loads and topologies. The network resources are best utilized when multiple paths are used to send data from source to destination. As per future perspective a study on fuzzy based multi-path routing algorithm will be carried out which give an edging over existing routing metrics.

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