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TCP-RP: A New Version of TCP based on Fuzzy Logic

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***Abstract*— TCP is the most popular end to end communication protocol in wired as well as wireless communication networks. At any point of time during the communication using TCP it is the size of the congestion window (cwnd) which determines the performance of the TCP. In this paper, we propose a new version of TCP: TCP-RP. TCP-RP uses fuzzy logic to determine optimum cwnd size during the Slow Start and Congestion Avoidance phase of TCP and improves network performance.**

***Keywords*— TCP-RP, congestion window(cwnd), acknowledgement (ACK) Sender Maximum Segment Size (SMSS), Bandwidth(BW), A, N.**

I. Introduction

The poor performance of TCP, particularly in wireless networks is because it was originally designed for wired networks and does not take into consideration wireless characteristics such as mobility, high loss probability, etc[3]. By observations and estimations it can be seen that during TCP operation, unnecessarily large cwnd size means high probability of contention and packet loss. On the other hand, small cwnd size means underutilization of bandwidth and hence under performance of the network.

Slow Start and Congestion Avoidance phases of TCP are the most important ones where size of the congestion window changes frequently. Hence, these are the phases which must have proper mechanism to determine the optimum size of the congestion window.

In this paper, we suggest a new version of TCP: TCP-RP. TCP-RP uses Fuzzy Logic for determining the optimum size of cwnd during Slow Start and Congestion Avoidance phases. The scheme uses Current Available Bandwidth(BW) and the Number of Bytes Acknowledged in the current acknowledgement (A) as input variables and gives out the estimated Number of Bytes to be added to the current cwnd size (we call it- N). While estimating the value of N the scheme ensures that N will never be greater than one SMSS. We claim that TCP-RP abides by the constraints given by latest networking standards such as rfc 5681[1] and rfc 3465 [5], and still, it improves network performance considerably.

II. Related Work

A. *Initial Size of Congestion Window*

RFC 3390[4] suggests: IW, the initial value of cwnd, MUST be set using the following guidelines as an upper bound.

if SMSS > 2190 bytes:

IW = 2 * SMSS bytes and MUST NOT be more than 2 segments

if (SMSS > 1095 bytes) and (SMSS <= 2190 bytes):

IW = 3 * SMSS bytes and MUST NOT be more than 3 segments

if SMSS <= 1095 bytes:

IW = 4 * SMSS bytes and MUST NOT be more than 4 segments **(1)**

Thus, IW MUST NOT be greater than 4380 Bytes.

B. *Incrementing cwnd Size*

RFC 5681[1] with reference to RFC 3465[5] suggested that: During Slow Start, while traditional TCP implementations have increased cwnd by precisely SMSS bytes upon receipt of an ACK covering new data, it's RECOMMENDED that TCP implementations increase cwnd, per:

cwnd + = min (A, SMSS) **(2)**

Where, A is the number of previously unacknowledged bytes acknowledged in the incoming ACK.

The basic guidelines for incrementing cwnd during congestion avoidance are:

- MAY increment cwnd by SMSS bytes
- SHOULD increment cwnd per equation (2) once per RTT
- MUST NOT increment cwnd by more than SMSS bytes

C. *Available Bandwidth Estimation*

In Huh, Jae Yong Lee and Byung Chul Kim [3] adapted idea proposed in TCP-Jersey [2] and suggested the following formula for Available Bandwidth Estimation:

$$BW_{E\_now} = \frac{BW_{E\_(k-1)} * RTT + PacketSize_k}{RTT * T_k} \qquad \textbf{(3)}$$

& for smoothing of Estimated Available Bandwidth by using Exponentially Weighted Moving Average (EWMA) method using α:

$$BW = BW_{E\_(K-1)} * \alpha + BW_{E\_now} * (1 - \alpha) \qquad \textbf{(4)}$$

Where,
BW = the current available bandwidth (smoothened)
$BW_{E\_(k-1)}$ = the calculated bandwidth at any $(k-1)^{th}$ ACK segment
BW_{E_now} = the current measured bandwidth
T_k = the time between $(k-1)^{th}$ ACK and $_{(k)}{}^{th}$ ACK.
$PacketSize_k$ = the total bytes of the previously transmitted packets, which were acknowledged between $(k-1)^{th}$ ACK and $(k-1)^{th}$ ACK
RTT = Round Trip Time

III. Proposed Scheme of TCP-RP

A. *Determining cwnd*

We use following rules for determining size of the congestion window (cwnd):

1. During Slow Start phase:
   for each ACK
   cwnd + = N
2. During Congestion Avoidance phase:
   for each RTT
   cwnd + = N

Figure 3.1 shows the mechanism of Slow Start and Congestion Avoidance phases of TCP-RP.

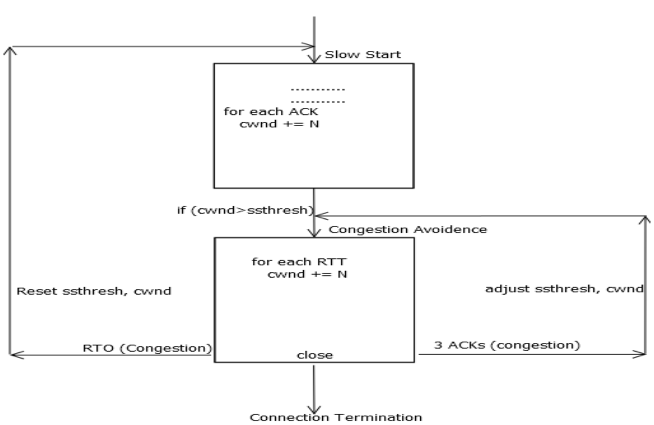

Figure 3.1: Slow Start & Congestion Avoidance Phases in TCP-RP

B. *Calculation of N*

Step 1: Calculate current Available Bandwidth (BW_{E_k}) using equations (3) & (4)
Step 2: Calculate value of **N** using Fuzzy logic based approximation model explained in the next section **c**.

C. *Fuzzy Approximation Model for calculating N*

i. Terminology

The table 3.1 given below lists the terms & their meaning (in order of their occurrence) used while designing Fuzzy Logic Based Approximation Model for calculating N.

Table 3.1 Terminology

Term	Meaning
BW	Current Available Bandwidth
VSB	Very small BW
SB	Small BW
MB	Medium BW
A	Number of bytes acknowledged in current ACK
VSA	Very small A
SA	Small A
MA	Medium A
LA	Large A
N	No. of bytes by which cwnd will be incremented after receiving an ACK
VSN	Very small N
SN	Small N
MN	Medium N
LN	Large N
VLN	Very Large N
µ(x)	Membership degree of element **x** in fuzzy set **BW**
µ(y)	Membership degree of element **y** in fuzzy set **A**
µ(z)	Membership degree of element **z** in fuzzy set **N**
BMAX	Maximum available value for **BW** (Depends on link bandwidth)
AMAX	Maximum available value for **A** (Depends on SMSS)
NMAX	Maximum available value for **N** (Depends on AMAX & SMSS)
fB	Partitioning factor for fuzzy set **BW**
fA	Partitioning factor for fuzzy set **A**
fN	Partitioning factor for fuzzy set **N**

ii. Formation of Linguistic Variables

We form three Linguistic Variables as follows:
Two input variables:

1) **BW = < VSB, SB, MB, LB >**

2) **A = < VSA, SA, MA, LA >**

& one Output Variable:

1) N = < VSN, SN, MN, LN, VLN >

iii. Building Fuzzy Sets (Fuzzification)

We build fuzzy sets for each of the Linguistic Variables in step I & assign membership function for each of these variables as following:

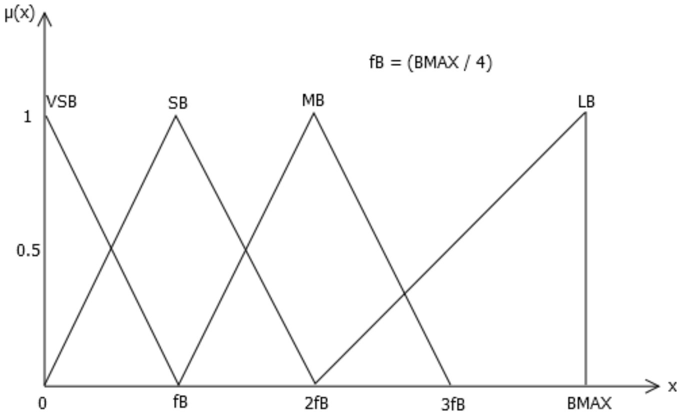

Figure 3.2 Fuzzy set for BW

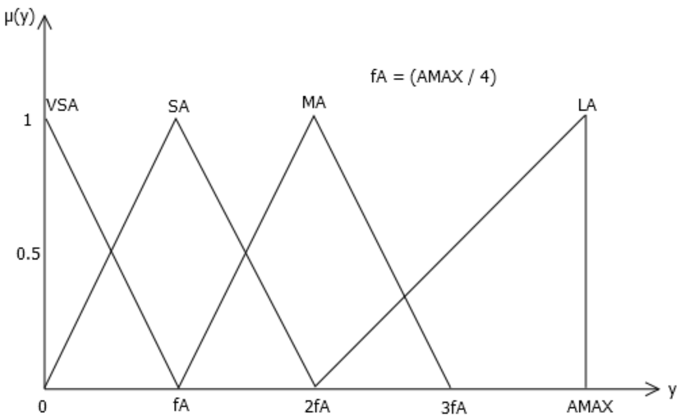

Figure 3.3 Fuzzy set for A

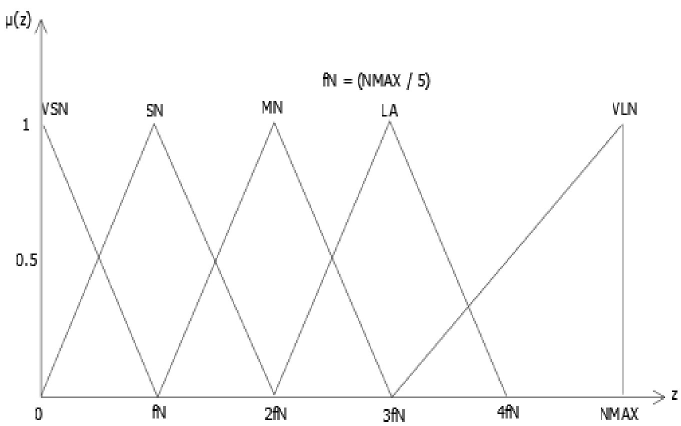

Figure 3.4 Fuzzy set for N

The membership equations of the fuzzy sets for BW, A & N will be as shown tables 3.2, 3.4 and 3.5 respectively.

Table 3.2 Membership Equations for BW

Linguistic Variable	Membership Equation	Range
VSB	(fB-x)/fB	0<x<=fB
SB	x/fB	0<x<=fB
	(2fB-x)/(2fB-fB)	fB<x<=2FB
MB	(x-fB)/(2fB-fB)	fB<x<=2FB
	(3fB-x)/(3fB-2fB)	2fB<x<=3fB
LB	(x-2fB)/(BMAX-2fB)	2fB<x<=BMAX

Table 3.3 Membership Equations for A

Linguistic Variable	Membership Equation	Range
VSA	(fA-y)/fA	0<y<=FA
SA	y/fA	0<y<=fA
	(2fA-y)/(2fA-fA)	fA<x<=2FA
MA	(y-fA)/(2fA-fA)	fA<y<=2FA
	(3fA-y)/(3fA-2fA)	2fA<y<=3FA
LA	(y-2fA)/(AMAX-2fA)	2fA<y<=AMAX

Table 3.4 Membership Equations for N

Linguistic Variable	Membership Equation	Range
VSN	(fN-z)/fN	0<z<=FN
SN	z/fN	0<z<=fN
	(2fN-z)/(2fN-fN)	fN<z<=2FN
MN	(z-fN)/(2fN-fN)	fN<z<=2FN
	(3fN-z)/(3fN-2fN)	2fN<z<=3FN
LA	(z-2fN)/(3fN-2fN)	2fN<z<=3fN
	(4fN-z)/(4fN-3fN)	3fN<z<=4fN
VL	(z-3fN)/(NMAX-3fN)	3fN<z<=NMAX

iv. Rule Base Formation

We formulate the Rule Base for calculating N as given by table 3.5.

Table 3.5 Rule Base Calculating N

	VSB	SB	MB	LB
VSA	VSN	SN	MN	LN
SA	SN	SN	MN	LN
MA	SN	MN	MN	LN
LA	SN	MN	LN	VLN

The Rule Base given in table 3.5 should be interpreted as:
If (Descriptor for BW && Descriptor for A) then
Descriptor for N;

E.g. if (VSA&&MB) then
MN;

v. Defuzzification

When given input values for BW & A; according to rule base in Step III we perform Rule Evaluation & Defuzzification as –

Rule Evaluation: It involves following steps-

1) Calculate all possible values for **μ(x)** & **μ(y)** for given input values

2) Calculate **μ(x) Intersection μ(y)** for all the values calculated in step 1) & choose the maximum of the resultant values.

Defuzzification:

3) For the maximum value chosen in step 2); calculate **μ(z)**

4) If multiple values are obtained for **μ(z);** take an average value. This is the final value of **N**.

IV. Theoretical Evaluation of TCP-RP Scheme

A set of test data is prepared. This test data is given as input to the Fuzzy Module for calculating N and the results based on the proposed model obtained theoretically. The results of theoretical estimation are shown in table 4.1.

Assumptions:

i) SMSS = 600 Bytes

ii) BMAX = 1000 Bps

iii) AMAX = 600 Bytes

iv) NMAX = 600 Bytes

Table 4.1 Sample Results

Test Set No.	BW(Bps) (input 1)	A(Bytes) (input 2)	N(Bytes) (result)
1.	**560**	**160**	**180**
2.	**598**	**221**	**240**
3.	**373**	**509**	**360**

V. Conclusion & Future Work

The results of theoretical estimations carried out on test data using TCP-RP are very encouraging. The protocol will be implemented in appropriate programming language such as C++ and using network simulator such as NS-2 the performance of TCP-RP against the performance of existing TCP variants will be measured.

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