Volume 5, Issue 3, March 2015 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

Survey on Congestion Control in High Speed Network

Auwalu Dahiru Gaya*, Hasheem Barau Danbatta, Abdullahi Garba Musa
Department of Computer & Engineering, Sharda,
Uttar Pradesh, India

Abstract-This paper presents a survey of congestion control approaches in high speed wired network by taking into account directions of source based congestion control research. Various survey papers reported in the literature, regarding source congestion control techniques, has been surveyed. The techniques deployed in source base congestion control are studied and compared in term of performance parameters and mechanism used. The main motivation of this work is to summarize source based approach techniques and compare those techniques in terms of years of evolution, performance parameter and technology used in their implemented.

Keywords— high speed network, Delay-based approach, Loss-based approach, hybrid-based approach.

I. INTRODUCTION

Today the number of internet users as well as the number of applications using internet have increased drastically due to the emergence of high speed network, which in turn increased the amount of traffic in the internet. The main side effect of this increased load is the problem of congestion in the network. Congestion control is considered as a problem of distributed nature, which requires a solution distributed at source–destination ends (transport layer). . The main motivation of this work is to summarize source based approach techniques and compare those techniques in terms of years of evolution, performance parameter and technology used in their implementation. Consequently many researchers have considered aspects of research for congestion control at source base perspective; Afanasyev et al. (2010) have done a comprehensive survey of various source based congestion control algorithms for different network environments.

The purpose of this literature survey is to review the congestion control research for high-speed network and characterize the different approaches to congestion control design, by considering their advantages and limitations.

II. RELATED WORK

In the literature the substantial survey work has been reported regarding congestion control. Some significant survey works related to the topic are as follows. Yang and Reddy (1995) have first proposed a taxonomy of congestion control approaches in packet switched network, based on the control theory. This taxonomy contributes a frame work which helps in the comparative study of the existing approaches and set a path toward the development of new congestion control approaches.

Labrador and Banerjee (1999) have given a comprehensive survey of selective packet dropping policies for the best-effort service of ATM and IP networks. They also had one a survey of control-theoretic analysis and design of end-to-end congestion control with a router based scheme. As alternatives to AQM algorithms, they also surveyed architectural approaches such as modification of source or network algorithms, and economic approaches including pricing or optimization of allocated resources.

Reddy and Lokanatha (2008) have first made an effort to comparatively analyse the high speed source based congestion control protocols based on various performance metrics like Throughput, Fairness, Stability, Performance, Bandwidth Utilization and Responsiveness and further the studied the limitations of these protocols meant for the High Speed Networks. Ho etal. (2008) surveyed state-of-the art of fast retransmit and fast recovery mechanisms of source based congestion control algorithms to address the lost packet problem, and presented a description of some useful algorithms, design issues, advantages, and disadvantages. They also presented taxonomy for fast retransmit and fast recovery mechanisms of some existing transport protocols which provides a unified terminology and a frame work for the comparison and evaluation of this class of protocols. Chandra and Subraman (2010) have presented a brief survey of major congestion control approaches and categorization characteristics, and elaborates the TCP-friendliness concept and then a state-of-the-art for the congestion control mechanisms designed for network they pointed out the major pros and cons of the various congestion control approaches and evaluated their characteristics.

Afanasyev et al.(2010) have done a comprehensive survey of various source based congestion control algorithms for different network environments. Their survey reflects that over the last 20 years many end-to-end techniques have been developed that addressed several problems with different levels of reliability and precision. They described each congestion control alternative, its strengths and its weaknesses and further they highlighted the fact that there search focus has changed with the development of the internet, from the basic problem of eliminating the congestion collapse phenomenon to problems of using available network resources effectively in different types of environments(wired, wireless, high-speed, long-delay, etc.).

III. CONGESTION CONTROL IN HIGH SPEED NETWORKS

The internet is a global infrastructure for information exchange that has revolutionized the social, economic, and political aspects of our lives. One of the most crucial building blocks of the internet is a mechanism for resource sharing and controlling congestion on the internet .Congestion can be defined as a network state in which the total demand for resources, e.g. bandwidth, among the competing users, exceeds the available capacity leading to packet or information loss and results in packet retransmissions (Papadimitriou, 2011). At the time of congestion in a computer network there will be a simultaneous increase in queuing delay, packet loss and number of packet retransmissions. In other words congestion refers to a loss of network performance when a network is heavily loaded. Keshav (2007) has defined it as "A network is said to be congested from the perspective of a user if the service quality noticed by the user decreases because of an increase in network load."

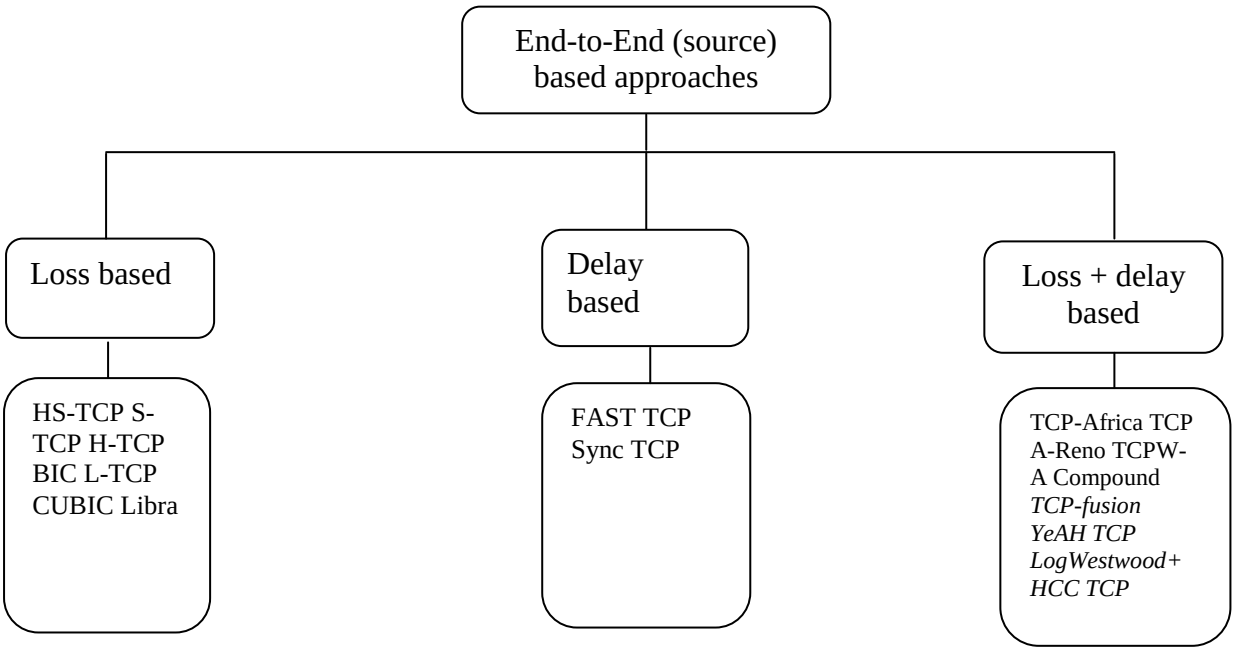
Since congestion causes data loss and large delays in data transmission therefore controlling or avoiding congestion is a critical problem in network management and design. Without proper congestion control mechanisms there is the possibility of inefficient utilization of resources, ultimately leading to network collapse (Haider,2004). Hence congestion control is an effort to adapt the performance of a network to changes in the traffic load without adversely affecting user's perceived utilities. Congestion control requires quick remedial measures both at the end host and at the routers. At the time of congestion the end host needs to decreases their data sending rates (or congestion windows) and routers need to drop packets until the congestion state is relieved.

Congestion control refers to techniques and mechanisms that can either prevent congestion, before it happens, or remove congestion, after it has happened. Yang and Reddy (1995) have divided congestion control mechanisms in to two broad categories: congestion avoidance (open-loop congestion control) and congestion recovery (closed-loop congestion control).The strategy of congestion avoidance is preventive in nature; it is aimed to keep the operation of a network at or near the point of maximum power, so that congestion will never occur. Whereas, the goal of congestion recovery is to restore the operation of a network to its normal state after congestion has occurred. Without a congestion recovery scheme, a network may crash entirely whenever congestion occurs. Therefore, even if a network adopts a strategy of congestion avoidance, congestion recovery schemes would still be required to retain throughput in the case of abrupt changes in a network that may cause congestion. Congestion control is a (typically distributed) algorithm to share network resources among competing traffic sources.

A network with a large bandwidth-delay product is commonly known as a high-speed network or long fat network (shortened to LFN and often pronounced "elephant"). As defined in RFC1072 (Braden and Jacobson, 1988), a network is considered an LFN if its bandwidth-delay product is significantly larger than 10^5 bits (12,500bytes). In data communications, bandwidth-delay product refers to the product of a data link's capacity (bits/s) and its end-to-end delay(s). The result, an amount of data measured in bits (or bytes), is equivalent to the maximum amount of data on the network circuit at any given time, i.e. data that has been transmitted but not yet received. Some important examples of systems where the bandwidth-delay product is large are high-capacity packet satellite channels e.g. DARPA's Wideband Net, a DS1-speed satellite. Terrestrial fiber-optical paths will also fall in to the LFN class; for example, across-country delay of 30ms at a DS3 bandwidth (45Mbps) also exceeds 10^6 bits.

IV. SOURCE BASED CONGESTION CONTROL

Source based congestion control methods are reactive in nature i.e. source host reacts after getting congestion signals from the networks, by reducing its transmission speed. TCP uses implicit congestion signals: packet loss or delay or the combination of both. Based on the types of congestion signals, source based approaches are further categorized as: loss based approach, Delay based approach, and hybrid approach:



- **Loss Base Approach:**

Loss based approach. The earliest loss based source based solution for congestion control in high speed network, "High Speed-TCP" was proposed by Floyd (2003). He commented that congestion control mechanisms of the Standard TCP limit the congestion windows that can be achieved by TCP in actual environments which results in poor utilization of network bandwidth. Therefore a new mechanism is required which effectively utilize a wide range of available bandwidths, and competes with Standard TCP more fairly in congested environments.

Kelly (2003) considered "better utilization of network bandwidth" and "fairness with Standard TCP" as two major challenges while designing TCP congestion control for high-speed network and proposed "Scalable TCP". Leith and Shorten (2004) raised the issue of backward compatibility of high speed TCP with Standard TCP while deployment of high speed TCP. He proposed "H-TCP" with focus on fairness, friendliness, responsiveness and throughput. Xu et al.(2004) commented that previous high speed TCP approaches only solved the bandwidth scalability and TCP friendliness problems. He pointed out another important issue termed as round trip time (RTT) unfairness for high speed congestion control and pro- posed "BIC TCP" as its solution.

Wang et al. (2005) considered dynamic bandwidth utilization as another challenge for high speed TCP and proposed a sender side enhancement method "TCPW-A TCP" by using the concept of agile probing. Rhee and Xu (2008) proposed "CUBIC TCP" by using a cubic window growth function and focused on improving the "TCP-friendliness" and "RTT-fairness" characteristic by making window growth rate RTT independent. Kliazovich et al. (2008) uses logarithmic increase function and proposed "LogWestwood + TCP" having low sensitivity with respect to RTT value, while maintaining high network utilization in a wide range of network settings. Marfia et al.(2005) considered RTT- fairness as severe problem because it adversely affects the long- RTT flow performance and proposed "TCP Libra" which ensure fairness and scalability regardless of the RTT, while remaining friendly towards legacy TCP.

- **Delay Based Approach**

Due to continuous advancement in computing, communication and storage technology, Wei et al .(2006) considered poor bandwidth scalability of standard TCP, as a key challenge for TCP congestion control in high-speed network. He proposed a first delay based source based method "FASTTCP" for congestion control in high speed network and considered throughput, fairness, stability and responsiveness as key issues for high-speed TCP. Xiu chao et al.(2009) have proposed "Sync-TCP" a delay based solution for congestion control in high speed environment and proposed a concept of flow level coordination for handling congestion. "Sync-TCP" guarantees a better trade-off between throughput and friendliness which is a serious issue while deploying new high speed TCP.

- **Hybrid Based Approach**

King et al. (2005) have proposed a first hybrid method "TCP-Africa" for high speed congestion control and raised a major issue of maintaining a careful balance between the increased aggressiveness and the fairness and safety while developing TCP for high bandwidth delay product network. Shimonishi and Murase (2005) considered TCP-Reno efficiency– friendliness trade off as a most important issue in highs-peed TCP design because TCP-Reno unfriendliness is the major hurdle in the way of high speed TCP deployment in current internet. They proposed "TCP-AR" (AdaptiveReno) to ensure friendliness to TCP-Reno, as well as efficiency in high-speed networks. Tan and Song(2006) emphasized that pure delay-based approaches may not work well if they compete with loss- based flows and proposed a hybrid approach "Compound TCP" which provides very good bandwidth scalability and at the same time achieves good TCP-fairness. Kaneko et al.(2007) proposed "TCP fusion" which exploits three useful characteristics of TCP-Reno, TCP-Vegas and TCP-Westwood in its congestion avoidance strategy and can obtain the highest throughput among existing TCP variants when there is unused residual capacity while its friendliness to the TCP-Reno is sufficiently satisfied, otherwise, it shares the same bandwidth to coexisting flows. Baiocchi et al.(2007) stated while designing high speed TCP, we should consider not only the full link utilization characteristic but preserve also the primary char- acteristic of congestion avoidance as it causes network instability and non-negligible degradations. They raised new issues like "induced network stress" and "robustness to random losses" for TCP in high speed environment. They proposed "YeAH TCP" a heuristic attempt to strike a balance among different opposite requirements. Xu et al.(2011) commented on existing high speed TCP, although these protocols perform successfully to improve the bandwidth utilization, they still have the weakness on the performance such as RTT-fairness, TCP-friendliness, etc. They stated that none of the existing approaches is overwhelmingly better than the other protocols and have the convincing evidence that could be generally deployed; the development of new high-speed TCP variants is still needed .They proposed "HCC TCP" which satisfies the requirements for an ideal TCP variant in high-speed networks, and achieve efficient performance on throughput, fairness, TCP-friendliness, robustness, etc.

Table I List of source based congestion control approaches (TCP) in high speed network.

YEAR	PUBLICATION TITLE	APPROACH	FEATURES	PERFORMANCE METRICS	Experimental method
2003	. Highspeed TCP for large congestion windows (RFC-	Loss based	AIMD with factors as functions of the congestion window	.Throughput, TCP friendliness	Simulation (Ns-2)

	3649)		size, limited slow-start		
2003	SCALABLE TCP: IMPROVING PERFORMANCE IN HIGHSPEED WIDE AREA NETWORKS	LOSS BASED	MIMD	FAIRNESS, FRIENDLINESS, RESPONSIVENESS,	Testbed experiment
2003	FAST TCP: FROM THEORY TO EXPERIMENTS	DELAY BASED	EQUATION-BASED WINDOW ADJUSTMENT	HROUGHPUT, FAIRNESS, RESPONSIVENESS,	Testbed experimen
2004	H-TCP: TCP FOR HIGH-SPEED AND LONG-DISTANCE NETWORKS	LOSS BASED	AIMD WITH NEW ADAPTIVE PARAMETERS	FAIRNESS, FRIENDLINESS, RESPONSIVENESS,	Simulation (Ns-2)
2004	BINARY INCREASE CONGESTION CONTROL (BIC) FOR FAST LONG-DISTANCE NETWORKS	LOSS BASED	BIMD, LIMITED SLOW-STAR	TCP FRIENDLINESS, BANDWIDTH SCALABILITY, RTT UNFAIRNESS	Simulation (Ns-2)
2005	TCP-AFRICA: AN ADAPTIVE AND FAIR RAPID INCREASE RULE FOR SCALABLE TCP	LOSS + DELAY BASED	DELAY SENSITIVE TWO-MODE CONGESTION AVOIDANCE RULE	UTILIZATION, EFFICIENCY, FAIRNESS, RTT UNFAIRNESS	Simulation (Ns-2)
2005	TCPW-A: TCP WITH SENDER-SIDE INTELLIGENCE TO HANDLE DYNAMIC, LARGE, LEAKY PIPES (TCP WESTWOOD WITH AGILE PROBING)	LOSS BASED WITH B/W ESTIMATION	USE ELIGIBLE RATE ESTIMATION (ERE) METHODS TO INTELLIGENTLY SET THE CONGESTION WINDOW (CWND) AND SLOW-START THRESHOLD (SSTHRESH) AFTER A PACKET LOSS	THROUGHPUT, FAIRNESS, FRIENDLINESS, CONVERGENCE	Simulation (Ns-2) Lab experiment
2006	COMPOUND TCP: A SCALABLE AND TCP-FRIENDLY CONGESTION CONTROL FOR HIGH-SPEED NETWORKS	LOSS + DELAY BASED	ADD A SCALABLE DELAY-BASED COMPONENT INTO THE STANDARD TCP RENO CONGESTION AVOIDANCE ALGORITHM.	BANDWIDTH SCALABILITY, TCP-FAIRNESS.	Simulation (Ns-2) Live intranet experiment
2007	TCP-FUSION: A HYBRID CONGESTION CONTROL ALGORITHM FOR HIGH-SPEED NETWORKS	LOSS + DELAY BASED WITH B/W ESTIMATION	TCP-FUSION EXPLOITS THREE USEFUL CHARACTERISTICS OF TCP- RENO, TCP-VEGAS AND TCP-WESTWOOD IN ITS CONGESTION AVOIDANCE STRATEGY	EFFICIENCY, FAIRNESS, FRIENDLINESS	Simulation (Ns-2) Testbed experiment
2008	CUBIC: A NEW TCP-FRIENDLY HIGH-SPEED TCP VARIANT	LOSS BASED	USES A CUBIC WINDOW GROWTH FUNCTION IN ORDER TO IMPROVE THE SCALABILITY OF TCP OVER FAST AND LONG	INTRA-PROTOCOL FAIRNESS, RTT-FAIRNESS, TCP-FRIENDLINESS	Testbed experiment

			DISTANCE NETWORKS.		
2009	SYNC-TCP: A NEW APPROACH TO HIGH SPEED CONGESTION CONTROL	DELAY BASED	EXPLOITS SYNCHRONIZATION, ADAPTIVE QUEUE-DELAY-BASED CWND DECREASE RULE, RTT-INDEPENDENT CWND INCREASE RULE	THROUGHPUT, TCP-FRIENDLINESS.	Ns-2 TCP Linux Testbed experiment
2010	TCP LIBRA: DERIVATION, ANALYSIS, AND COMPARISON WITH OTHER RTT-FAIR TCPS	LOSS BASED	MULTIPLYING THE CONGESTION WINDOW BY THE SQUARE OF THE RTT DURING THE ADDITIVE INCREASE POR- TION OF THE TCP ALGORITHM.	RTT-FAIRNESS TCP-FRIENDLINESS. BANDWIDTH SCALABILITY.	Simulation (Ns-2) Testbed experiment
2011	HCC TCP: HYBRID CONGESTION CONTROL FOR HIGH-SPEED NETWORKS	LOSS + DELAY BASED (SWITCHING)	THE TWO APPROACHES (DELAY + LOSS) IN THE ALGORITHM ARE DYNAMICALLY TRANSFERRED INTO EACH OTHER ACCORDING TO THE NETWORK STATUS.	THROUGHPUT, FAIRNESS, TCP-FRIENDLINESS, ROBUSTNESS	Simulation (Ns-2)

V. NETWORK PERFORMANCE PARAMETERS IN SORCE BASED CONGESTION CONTROL

Performance parameters considered for source based congestion control techniques are listed in the Table II, which shows various source based congestion control approaches and their respective performance parameters taken into consideration represented by the letter "y" in their respective cells. The blank cells show those performance parameters which are not taken into account in the respective approach.

It can be observed from Table5 that the three performance parameters TCP friendliness, Fairness and efficiency have considered most important parameters while designing source based congestion control algorithms. TCP friendliness means maintaining fairness among the traditional TCP connections and High speed TCP connections. Hasegawa and Murata (2001) pointed out that traditional TCP has already been used widely in the current internet, it is difficult for the new high speed protocol to be accepted if it is not downward compatible to the existing TCP. A number of protocols, such as High Speed TCP and Scalable TCP, have been proposed; however, their lack of friendliness to existing protocols has hampered their wide deployment in public networks (Santi and Fonseca, 2011). Thus TCP friendliness is a key issue while deployment of High speed TCP in current internet. Throughput efficiency and fairness are considered as major design issues because in high speed network large amount of bandwidth is available which should be exploited efficiently in a fair manner. RTT unfairness, fairness and bandwidth scalability have also con- sidered as important parameters for source based congestion control algorithms. RTT unfairness problem arises when multiple flows with different RTT delays are competing for the same bottleneck bandwidth.

Lakshman and Madhow (1997) have found that TCP throughput is inversely proportional to RTTα where $1<\alpha<2$. Thus flow having larger RTT value will not get its fair share of link bandwidth as compared to flow having smaller RTT value. RTT unfairness is considered as a severe problem on the way of deployment of source based congestion control approaches in high speed networks (Xu et al., 2004). The performance parameter fairness was considered by various researchers for the evaluation of source based approaches. The main goal of fairness is to share the network resource in a fair manner. The performance parameter fairness has two dimensions, one is inter-protocol fairness and another one is intra-protocol fairness. In case of high speed network bandwidth scalability is also considered as an important issue because source based approach having scalable window increasing rule that not only can efficiently probe the link capacity, but also reacts early to congestion by sensing the changes in RTT

Faster convergence to a fair bandwidth share is also considered as a vital issue because source based approach must adapt to changing network conditions on reasonable time scales. Convergence times deal with the time for convergence to fairness between an existing flow and a newly starting one, and area special concern for environments with high-bandwidth long-delay flows. Convergence times also concern the time for convergence to fairness after a sudden change such as a change in the network path, the competing cross-traffic

Responsiveness is one of the key concerns in the design of congestion control mechanisms which concern with the response times to sudden congestion in the network. On the one hand, congestion control mechanisms should respond reasonably promptly to sudden congestion from routing or bandwidth changes or from a burst of competing traffic. At

the same time, congestion control mechanisms should not respond too aggressively to transient changes,e.g., to a sudden increase in delay that will dissipate in less than the connection's round-trip time. Evaluating the response to sudden or transient changes in bandwidth-delay product can be of particular concern for slowly responding congestion control mechanisms. One goal is that of stability, in terms of minimizing oscillations of queuing delay or of throughput. In practice, stability is frequently associated with rate fluctuations or variance. Rate variations can result in fluctuations in router queue size and therefore of queue over flows. These queue over flows can cause loss synchronizations across coexisting flows and periodic under-utilization of link capacity, both of which are considered to be general signs of network instability. Thus, measuring the rate variations of flows is often used to measure the stability of transport protocols. Xu et al. (2011) have first considered robustness of TCP against reverse traffic as a performance parameter in High speed TCP design. Because throughput performance in forward path is significantly affected by the reverse traffic, and the throughput of the source traffic decreases as the queuing delay increases on the reverse path. In other words as the congestion on the reverse path increases, the throughput of the flows degrades although there is available bandwidth on the forward path.

Table II List of performance parameters for source based congestion control in high speed network.

High speed TCP (Floyd, 2003)	TCP friendliness	Fairness	RTT unfairness	Responsive-ness	Efficiency	Bandwidth scalability	Convergence speed	Stability	Robustness
Scalable TCP (Kelly,2003)	y	y			y	y	y		
H-TCP (Leith andShorten,2004)					y	y	y	y	
BIC-TCP (Xuetal.,2004)	y	y	y		y	y	y	y	
FAST TCP (Weietal.,2006)	y	y		y	y		y	y	
TCP-Africa (King etal.,2005)	y	y	y		y	y			
TCP-A Reno (Shimonishi and Murase2005)	y	y			y				
TCPW-A (Wangetal.,2005)	y	y			y	y	y		
Compound TCP (Tan and Song,2006)	y	y	y	y	y	y			
TCP-fusion (Kaneko etal.,2007)	y	y	y		y				
YeAHTCP (Baiocchi etal.,2007)	y	y	y		y				
TCP LogWestwoodþ (Kliazovich et al., 2008)	y	y	y		y				
CUBIC (Rhee andXu,2008)	y	y	y		y	y	y	y	
Sync-TCP (Xiuchao etal.,2009)	y	y	y		y		y		
TCP Libra (Marfia etal.,2005)	y	y	y		y	y	y	y	
HCC TCP (Xuetal.,2011)	y	y	y	Y	y				Y

VI. CONCLUSION

This survey explores literature review of congestion control algorithms in the context of high speed wired networks. This survey covers the source based congestion control. Congestion control problem is assumed as a challenging problem by academia and industry. Some approaches assume congestion control as a partial problem but most of the approaches

considered network congestion as fully fledged problem. A demonstration of various approaches for source based congestion control approaches has been study in order to find out strengths and weaknesses of those approaches. Comparative study of performance of existing methods based on different performance metrics has been mentioned. It can be observed that the three performance parameters TCP friendliness, Fairness and efficiency have considered most important parameters while designing source based congestion control algorithm.

ACKNOWLEDGMENT

We thank number of people like Mr Devendra Gautam, pof Ishan Ranjan,Dr. Ravi Rastoji,etc

REFERENCES

[1] Li YT, Leith D, Shorten RN. Experimental evaluation of TCP protocols for high-speed networks. IEEE/ACM Transactions on Networking 2007;15(5): 1109–22.

[2] Chan YC, Chan CT, Chen YC. Design and performance evaluation of an improved TCP congestion avoidance scheme. IEE Proceedings: Communications 2004;151(1):107–11

[3] Kaneko K, Fujikawa T, Su Z, Katto J. TCP-fusion: a hybrid congestion control algorithm for high-speed networks. In: Proceedings of the PFLDnet. Marina Del Rey (Los Angeles, California): ISI; February 2007.

[4] Wei DX, Jin C, Low SH, Hegde S, FAST TCP. Motivation, architecture, algorithms, performance. IEEE/ACM Transactions on Networking 2006;14(6):1246–5

[5] Papadimitriou D.RFC6077 – open research issues in internet congestion control. Internet engineering task force. RFC;February2011

[6] Cui T, Andrew L, Zukerman M, Tan L. Improving the fairness of FAST TCP to new flows. IEEE Communications Letters 2006;10(5):414–6.

[7] NetherLight. /http://www.science.uva.nl/research/air/projects/optical/S; 2010.

[8] KellyT. Scalable TCP: improving performance in high speed wide area networks. Computer Commun Rev2003;33(2):83–91.

[9] Keshav S. What is congestion and what is congestion control. In: Presentation at IRTF ICCRG workshop. PFLDnet 2007. Los Angeles (California, USA); February 2007.

[10] Xia Y, Subramanian L, Stoica I, Kalyanaraman S. One more bit is enough. Computer Communication Review 2005;35:37–48.

[11] Xu L, Harfoush K, Rhee I. Binary increase congestion control (BIC) for fast long- distance networks. In: Proceedings of IEEE INFOCOM; 2004.

[12] Xu W, Zhou Z, Pham DT, Ji C, Yang M, Liu Q. Unreliable transport protocol using congestion control for high-speed networks. Journal of Systems and Software

[9] [1] Lisong Xu, Khaled Harfoush, and Injong Rhee: Binary Increase Congestion Control (BIC) for Fast Long-Distance Networks.

[10] [2] Sangtae Ha, Injong Rhee, Lisong Xu: CUBIC: A New TCP Friendly High Speed TCP Variant.

[11] [3] David X. Wei, Cheng Jin, Steven H. Low, Sanjay Hegde: FAST TCP: Motivation, Architecture, Algorithms, Performance: IEEE/ACM TRANSACTIONS ON NETWORKING, VOL. 14, NO. 6, DECEMBER 2006

[12] Xiuchao Wu, Mun Choon Chan, A. L. Ananda and Chetan Ganjihal, Sync-TCP: A New Approach to High Speed Congestion Control.

[13] Kun Tan Jingmin Song, Qian Zhang, Murari Sridharan, Compound TCP: A Scalable and TCP-FriendlyCongestion Control for High-speed Networks

[14] Shao Liu_, Tamer Bas¸ar, R. Srikant, TCP-Illinois: A loss- and delay-based congestion control algorithm for high-speed networks, Performance Evaluation 65 (2008) 417–440

[15] Wenjun Xu, ZudeZhou, D.T.Pham, C.Ji, M.Yang, QuanLiu, Hybrid congestion control for high-speed networks, Journal of Network and Computer Applications, springer, 34 (2011) 1416–1428.

[18] Alonso SH, Perez MR, Gonzalez AS, Veiga MF, Garcia CL. Improving TCP Vegas fairness in presence of backward traffic. IEEE Communications Letters 2007;11(3):273–5.

[19] Leith DJ, Shorten RN. H-TCP protocol for high-speed long-distance networks. In: Proceedings of second workshop protocols fast long distance networks; 2004

[20] Gu Y, Grossman RL. UDT: UDP-based data transfer for high-speed wide area networks. Computer Networks 2007;51(7):1777–99.

[21] Kelly T. Scalable TCP: improving performance in highspeed wide area networks. Computer Communication Review 2003;33(2):83–91.

[22] Low SH, Peterson LL, Wang L. Understanding TCP vegas: a duality model. Journal of the ACM 2002;49(2):207–35.

[23] Tan L, Yuan C, Zukerman M, FAST TCP. Fairness and queuing issues. IEEE Communications Letters 2005;9(8):762–4.

[24] YangC, Reddy A. A taxonomy for congestion control algorithms in packet switching networks.IEEENetwMag1995;9(4):34–45

