INTERNATIONAL JOURNAL OF RESEARCH IN COMPUTER APPLICATIONS AND ROBOTICS
ISSN 2320-7345

A SURVEY ON EXPLICIT FEEDBACK BASED CONGESTION CONTROL PROTOCOLS

Nasim Ghasemi[1], Shahram Jamali[2]

[1] Department of Computer Engineering, Tabriz Branch, Islamic Azad University, Tabriz, Iran,
[2] Department of Computer Engineering, University of Mohaghegh Ardabili, Ardabil, Iran,
nasim_ghasemi88@yahoo.com, jamali@iust.ac.ir

Abstract

As usage of network goes increasing day by day, managing network traffic becomes a very difficult task. It is important to avoid high packet loss rates in the Internet. Congestion is the one of the major issue in the present networks. Congestion Control is one of the solutions adopted to solve the congestion issue and to control it. Congestion Control of the Internet is an end to end mechanism. In this mechanism, end systems estimate congestion level inside the network and they don't receive any explicit notifications to grasp exact congestion level. Explicit feedback based congestion control schemes have shown to enhance network performance, in terms of utilization, packet loss and delay. In these schemes, using more accurate representation of network load levels is likely to lead to a more efficient way of communicating congestion information to hosts. Increasing the amount of congestion information, however, may end up adversely affecting the performance of the network. In this paper a study is made on explicit feedback based congestion control techniques that are proposed. Active Queue Management (AQM) is one such mechanism which provides better control over congestion.

Keywords*:* Active Queue Management, RED, Congestion Control, Explicit feedback, TCP, ECN.

1. Introduction

Link capacities [1] and incorporation of wireless WANs into the Internet), coupled with the need to support diverse QoS requirements; bring about challenges that are likely to become problematic for TCP. This is because (1) TCP reacts adversely to increases in bandwidth and delay and (2) TCP's throughput and delay variations make it unsuitable for many real-time applications. These limitations may lead to the undesirable situation where most Internet traffic is not congestion-controlled; a condition that is likely to impact the stability of the Internet. TCP was designed to suit an environment where the BDP was typically less than ten packets, but BDP of many Internet paths is orders of magnitude larger. To address these issue researchers have proposed transport protocols that can be placed into three broad categories, (a) end-to-end (e2e) schemes with implicit feedback, (b) e2e schemes with explicit feedback and (c) network-based solutions. e2e schemes with implicit feedback treat the network as a black box and infer congestion via implicit signals such as loss and delay. Research studies have shown that using only packet loss and/or delay as a signal of congestion poses fundamental limitations in achieving high utilization and fairness while maintaining low bottleneck queue and near-zero packet drop rate on high BDP paths [2,3]. The benefit of using such schemes is in the ease of their deployment because they require modifications only at the end-hosts. e2e schemes with explicit feedback (such as TCP + AQM/ECN proposals [4-8] and VCP [9]) use one or few bits of explicit feedback from the network, however, the bulk of their functionality still resides at the end-hosts. They typically require changes at the end-hosts with incremental support from the network. Such schemes have been shown to perform better than their counterparts with implicit feedback. However, it is unclear how the amount of congestion feedback information affects performance;

2. Background

2.1 TCP protocol

The congestion control algorithm in the Transmission Control Protocol (TCP) has been widely credited for the stability of the Internet. However, future trends in technology (e.g., increases in link capacities and incorporation of wireless WANs into the Internet), coupled with the need to support diverse QoS requirements; bring about challenges that are likely to become problematic for TCP. According to Figure1 TCP reacts adversely to increases in bandwidth and delay. Therefore TCP is not suitable for high BDP paths.

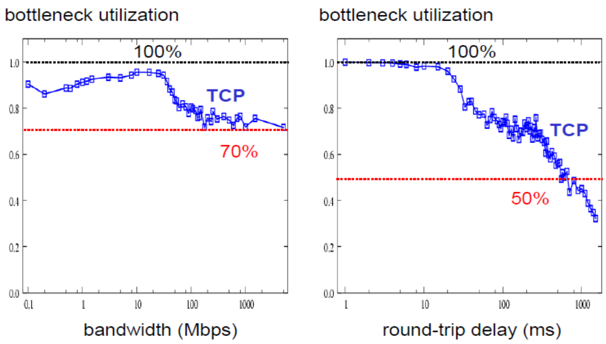

Figure 1: reaction of TCP to increases in bandwidth and delay

2.2 Active Queue Management

Active queue management mechanisms detect congestion before the queue overflows and provide an indication of this congestion to the end nodes [10]. With this approach TCP does not have to rely only on buffer overflow as the indication of congestion since notification happens before serious congestion occurs. One such active management technique is RED.

3. Explicit feedback based protocols

Explicit feedback based congestion control schemes can capture network congestion status more accurately than pure end-to-end schemes.

3.1 Queue based protocols

Router congestion detection in these protocols is the queue based.

3.1.1 TCP+RED/ECN

This protocol is a Queue based explicit congestion control protocol. The protocol uses a one-bit explicit congestion notification instead of using packet drop as an implicit notification and random early detection (RED) is an active queue management mechanism.

3.*2* load based protocols

Router congestion detection in these protocols is load based. One of the proper and accurate mechanisms to ensure quality of service and prevent congestion in the network, the use of load factor based congestion control protocols. In this protocols, load level of network (demand to capacity ratio), is used as a congestion signal , the signal contains important information about the network and sent as feedback to the sources and these sources accordingly adjust their send rate and prevent the occurrence of congestion in the network . According to equation (1), load factor as the ratio of demand to capacity or ratio of traffic received during tp and queue size to the link bandwidth can be expressed. so that tp is the link load factor measurement interval.

$$Load\ factor = \frac{demand}{capacity} = \frac{arrival\ traffic + queue\ size}{link\ bandwidth \times tp} \qquad (1)$$

Load factor based protocols to achieve efficient and fair bandwidth allocation and minimizing packet loss in high bandwidth delay product network were designed. In this algorithms two issues that need to be considered include:1-The number of congestion levels, which should be specified by the feedback signal and announced to the sources. 2-window adjustment policy to the fair allocation of network bandwidth in the sources are taken. Two of this protocols are: VCP[9] and MLCP[11].

3.*2*.1 VCP protocol

Achieving efficient and fair bandwidth allocation while minimizing packet loss in high bandwidth-delay product networks has long been a daunting challenge. Existing end- to-end congestion control (*e.g.*, TCP) and traditional congestion notification schemes (*e.g.*, TCP+AQM/ECN) have significant limitations in achieving this goal. While the recently proposed XCP protocol addresses this challenge, XCP requires multiple bits to encode the congestion-related information exchanged between routers and end-hosts. Unfortunately, there is no space in the IP header for these bits, and solving this problem involves a non-trivial and time consuming standardization process. In 2005 was designed and implemented a simple, low- complexity protocol, called Variable-structure congestion Control Protocol (VCP), that leverages only the existing two ECN bits for network congestion feedback, and yet achieves comparable performance to XCP[12], *i.e.*, high utilization, according to Figure2.

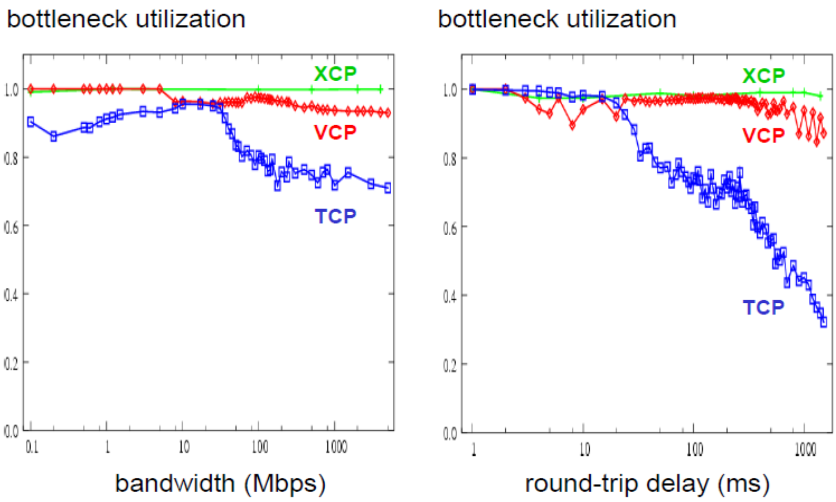

Figure 2: High effiency in VCP protocol in comparison to TCP protocol

This Protocol in order to achieve higher performance, lower queue length and minimum packet loss was designed. VCP protocol like TCP+AQM/ECN is an end to end congestion control mechanism and has a similar architecture with TCP+AQM/ECN protocol. With the difference that router congestion detection in TCP+AQM/ECN protocol is based on queue whereas in VCP protocol is based on load. Each router computes the load factor (ρl) during every tp interval of time for each of its output links l. Here, λ_l is the amount of input traffic during the period *tp*, q_l is the persistent queue length during this period, K_q controls how fast the persistent queue drains, γ_l is the target utilization [9] (set to a value close to 1), and *Cl* is the link capacity.

(2)

According to Figure3 load factor in form of two ECN bits is quantized and coded. So that $\hat{\rho}_l$ is two bit quantized load factor on link and *l* is a non-decreasing function of the raw load factor ρl and can be represented by a two-bit code $\hat{\rho}_l^c$.

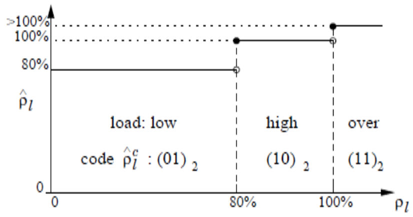

Figure 3: two-bit quantized load factor

Given that VCP uses two-bit congestion signal as feedback, thus able to identify three congestion level. According to Figure4 end users based on the feedback received adapt their windows with Multiplicative Increase (MI), Additive Increase (AI) and Multiplicative Decrease (MD) or (MI-AI-MD) window adjustment policies.

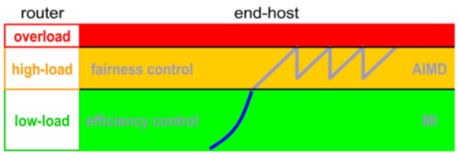

Figure 4: VCP protocol behaoior

According to Figure5, in VCP two-bit ECN is used as congestion signal whereas according to Fig6 in TCP+AQM/ECN, one-bit is used as congestion signal.

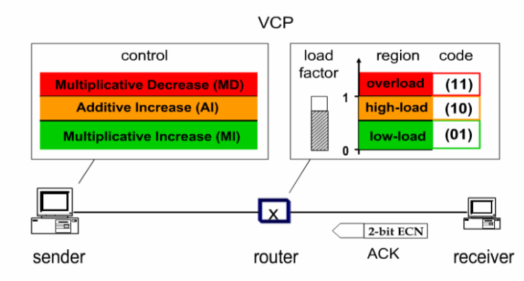

Figure 5: The VCP protocol congestion signal

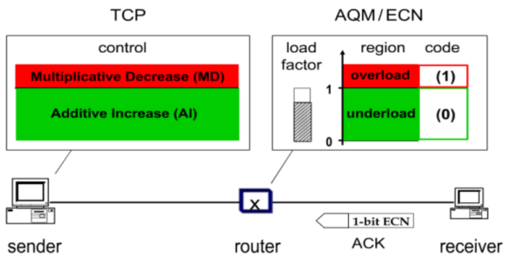

Figure 6: The TCP+AQM/ECN protocol congestion signal

Given that in VCP protocol is used three congestion level, therefore the protocol has lower congestion window oscillation than TCP+AQM/ECN protocol. Table1 shows the VCP protocol in comparison to XCP, TCP and TCP+AQM/ECN protocols in term of explicit information about the amount of congestion in the network. According to following table, XCP protocol requires multiple bits to transmit information about network congestion, which causes considerable overheads that imposed on the router. VCP protocol despit using less congestion bits (2 bits) in a wide range of network scenarios is scalable.

Table1: VCP protocol in comparison to other protocols in terms of explicit information amount

Protocol	**Amount of explicit information**
XCP	Multiple bits to encode the congestion-related information was required and were imposed very overheads to the router
VCP	Two-bits to represent the congestion levels low load, high load was used
TCP+AQM/ECN	One bit to represent the congestion levels high load and overload was used
TCP	not used explicit feedback and not operate the based on duplicate ACK and timeout

3.*2.2* MLCP protocol

MLCP (Multi Level feedback Congestion control Protocol) was presented in 2009[11]. One of the MLCP goals is evaluation the interaction between increasing information (number of encoded bits) of feedback signals and efficiency improvement and other goal is evaluating the window adjustment policies in order to provide efficient and fairness in High-BDP, while maintaining near-zero packet drop rate and low persistent queue length. MLCP results show that 3-bit feedback is sufficient for achieving near-optimal rate convergence to an efficient bandwidth allocation [11]. According to Figure7, 2-bit, 3-bit, 4-bit and 15-bit feedback schemes were compared in terms of RTT, also according to Figure8, 2-bit and 3-bit feedback schemes were compared in terms of utilization. Results show that 3-bit feedback in comparison to 2-bit feedback has significantly improvement and the Increasing signal data more than 3-bit feedback, leads only a slight improvement in total time.

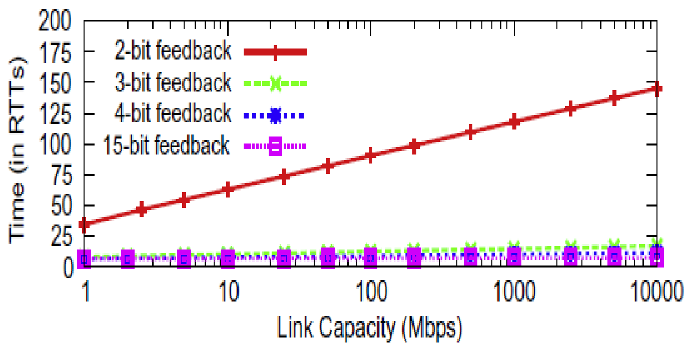

Figure7: Comparison of the time required to achieve 80% utilization for 2-bit, 3-bit, 4-bit and 15-bit feedback schemes

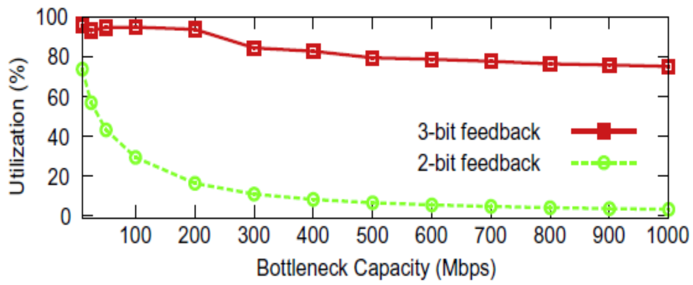

Figure8: The Comparison of the utilization for 2-bit and 3-bit feedback schemes.

Also based on the studies conducted, it has been demonstrated that use of 3-bit signals in comparison to 2-bit signals can be cause rapid flow completion. According to Figure9, Average Flow Completion Time (AFCT) or (response time). in 3-bit feedback schemes is lower than 2-bit feedback schemes, thus given that VCP protocol is a 2-bit congestion control method, dose not indicate good performance.

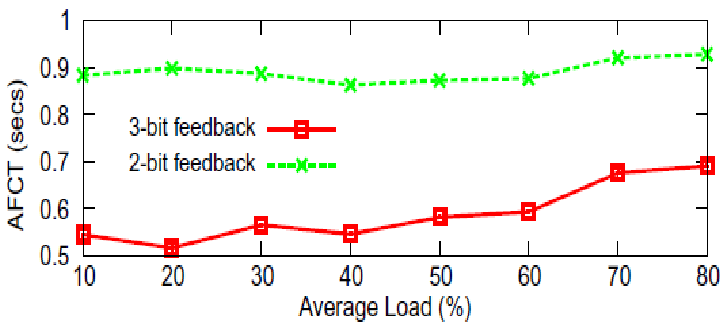

Figure9: The Comparison of the AFCT for 2-bit and 3-bit feedback schemes.

In this protocol load factor in the bottleneck link, similar VCP protocol is calculated, Where σ is load factor and K_q is set to 0.75.

$$\sigma = \frac{\lambda_l + K_q \cdot q_l}{\gamma_l \cdot C_l \cdot t_p} \qquad (3)$$

MLCP protocol in comparison to VCP protocol also used the Inversely-proportional Increase (II) window adjustment policy. Where a MLCP sender applies MI, AI, II or MD, based on the value of the encoded load factor received from the network. When the load factor dt the bottleneck is below 80%, each MLCP sender applies load factor guided MI, each sender applies AI until σ becomes 95% after which II is applied. When the system moves into the overhead region (σ≥100%), each sender applies MD. The following equations describe the control laws in terms of congestion window adjustments:

$$\text{MI: } cwnd(t + rtt) = cwnd(t) \times (1 + \xi(\sigma)) \qquad (4)$$

$$\text{AI: } cwnd(t + rtt) = cwnd(t) + \alpha \qquad (5)$$

$$\text{II: } cwnd(t + rtt) = cwnd(t) + \frac{\alpha}{\sqrt{cwnd(t)}} \qquad (6)$$

$$\text{MD: } cwnd(t + \Delta) = cwnd(t) \times \beta(\sigma) \qquad (7)$$

Where rtt= t_p, $\Delta \rightarrow 0$, α=1.0, $\xi(\sigma)=K.\frac{1-\sigma}{\sigma}$, 0 <$\beta(\sigma)$<

Table2 shows comparing MLCP and VCP protocols. As you can see, MLCP protocol in comparison to VCP protocol has the high accuracy and efficiency, also average flow completion time in the MLCP is lower, that show the higher efficiency and better performance of MLCP protocol

.

Table2: The comparison of VCP and MLCP protocols

protocol	description
VCP	Use of 2-bit congestion signal and less accuracy to the expression congestion levels and high response time (AFCT)
MLCP	Use of 3-bit congestion signal to the expression congestion levels high accuracy and high response time (AFCT) due to lower RTT

4. Conclusion

In this paper, we compared the explicit feedback based congestion control protocols, include of TCP+RED/ECN, XCP, VCP and MLCP protocols. In comparison of VCP with TCP+RED/ECN and XCP, with a few minor changes over TCP + AQM / ECN, VCP is able to approximate the performance of XCP. also we conclude while 2-bit scheme is far from optimal, using 3-bit is sufficient for achieving near-optimal performance in terms of rate of convergence to efficiency. Therefore MLCP protocol in comparison to VCP protocol has the high accuracy and efficiency.

REFERENCES

[1] ITU's Asia-Pacific Telecommunication and ICT Indicators Report Focuses on Broadband Connectivity: Too much or too little?, <http://www.itu.int/newsroom/press_releases/2008/25.html>, 2008.

[2] S. Floyd, 2003, Highspeed TCP for large congestion windows, in: IETF RFC3649.

[3] H. Bullot, R.L. Cottrell, 2003, Evaluation of Advanced TCP Stacks on Fast Long-Distance Production Networks., URL <http://www.slac. stanford.edu/grp/scs/net/talk03/tcp-slac-nov03.pdf>.

[4] S. Floyd, V. Jacobson, 1993, Random Early Detection Gateways for Congestion Avoidance, IEEE/ACM Transaction on Networking (4), pp. 397–413.

[5] S. Athuraliya, V. Li, S. Low, Q. Yin, 2001, REM: active queue management, IEEE Network 15 (3), pp. 48–53.

[6] K.K. Ramakrishnan, S. Floyd, 2001, The addition of explicit congestion notification (ECN) to IP, in: IETF RFC 3168.

[7] C. Hollot, V. Misra, D. Towsley, W. Gong, 2002, Analysis and design of controllers for AQM routers supporting TCP flows, IEEE/ACM Transaction Automatic Control 47 (6), pp. 945–959.

[8] S. Low, F. Paganini, J. Wang, J. Doyle, Linear stability of TCP/RED and a scalable control, Computer Networks Journal 43 (5), 2003, pp. 633–647.

[9] Y. Xia, L. Subramanian, I. Stoica, S. Kalyanaraman, 2005, One more bit is enough, in: Proceedings of ACM SIGCOMM.

[10] Ramakrishnan, K. and S. Floyd, January 1999, A Proposal to add Explicit Congestion Notification (ECN) to IP, RFC 2481.

[11] I. A. Qazi and T. Znati, 2009, On the design of load factor based congestion control protocols for next-generation networks, in IEEE INFOCOM.

[12] D. Katabi, M. Handley, and C. Rohrs, Aug 2002Internet Congestion Control for High Bandwidth-Delay Product Networks, in Processings of ACM SIGCOMM.