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Study of Various Congestion-control Protocols in Network

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Abstract— Congestion control in computer network is an important issue to be addressed. Various congestion protocols are used for avoiding congestion in network. The survey of congestion control protocols in network is important and necessary for smart transport system. This paper discusses the advantages/disadvantages and the applications of various congestion control protocols for wired/wireless networks. It explores the motivation behind the designed, and traces the evolution of these congestion control protocols.

Index Terms— ECN, VCP, XCP,DPCP, TFRC, LF

1 INTRODUCTION

Congestion control concerns controlling traffic entry into a telecommunications network, so as to avoid congestive collapse by attempting to avoid oversubscription of any of the processing or link capabilities of the intermediate nodes and networks and taking resource reducing steps, such as reducing the rate of sending packets. Congestion is an important issue that can arise in packet switched network. Congestion is a situation in Communication Networks in which too many packets are present in a part of the subnet, performance degrades. Congestion in a network may occur when the load on the network is greater than the capacity of the network. In data networking and queuing theory, network congestion occurs when a link or node is carrying so much data that its quality of service deteriorates. Typical effects include queuing delay, packet loss or the blocking of new connections.

2 CONGESTION CONTROL PROTOCOLS

There are many ways to classify congestion control algorithms:

i. By the type and amount of feedback received from the network: Loss; delay; single-bit or multi-bit explicit signals
ii. By incremental deployability on the current Internet: Only sender needs modification; sender and receiver need modification; only router needs modification; sender, receiver and routers need modification.
iii. By the aspect of performance it aims to improve: high bandwidth-delay product networks; lossy links; fairness; advantage to short flows; variable-rate links
iv. By the fairness criterion it uses: max-min, proportional, "minimum potential delay"

2.1 Protocols based of Congestion Avoidance

a. TCP-Tahoe[23]

Tahoe uses 'Additive Increase Multiplicative Decrease'(AIMD) for congestion avoidance. In this case a packet loss is taken as a sign of congestion and TCP-Tahoe saves the half of the current window as a threshold value. It then set cwnd to one and starts slow start until it reaches the threshold value. After that it increments linearly until it encounters a packet loss. Thus it increase it window slowly as it approaches the bandwidth capacity. The problem with TCP-Tahoe is that to detect a packet loss it takes a complete timeout interval and in fact, in most implementations it takes even longer because of the coarse grain timeout. In some it sends cumulative acknowledgements in place of immediate ACK's, therefore it follows a 'go back n 'approach. Thus every time when a packet is lost it waits for a timeout and the pipeline is emptied. This offers a major cost in high band-width delay product links.

b. TCP-RENO[24]

TCP RENO adds some intelligence over Tahoe so that lost packets are detected earlier and the pipeline is not emptied every time a packet is lost. Reno suggest an algorithm called 'Fast Re-Transmit' in which when 3 duplicate ACK's are received, it is taken as a sign that the segment was lost, so retransmission of the segment without waiting for timeout is done. Reno performs very well over TCP when the packet losses are small. When there are multiple packet losses in one window then RENO doesn't perform too well and it's performance is almost the same as Tahoe under conditions of high packet loss.

c. NEW-RENO[25]

New-RENO is a slight modification over TCP-RENO. It is able to detect multiple packet losses and thus is much more efficient than TCP RENO in the event of multiple packet losses. Like TCP-RENO, New-RENO also enters into fast-retransmit when it receives multiple duplicate packets. New-RENO differs from TCP-RENO in that it doesn't exit fast recovery until all the data which was out standing at the time it entered fast-recovery is acknowledged.

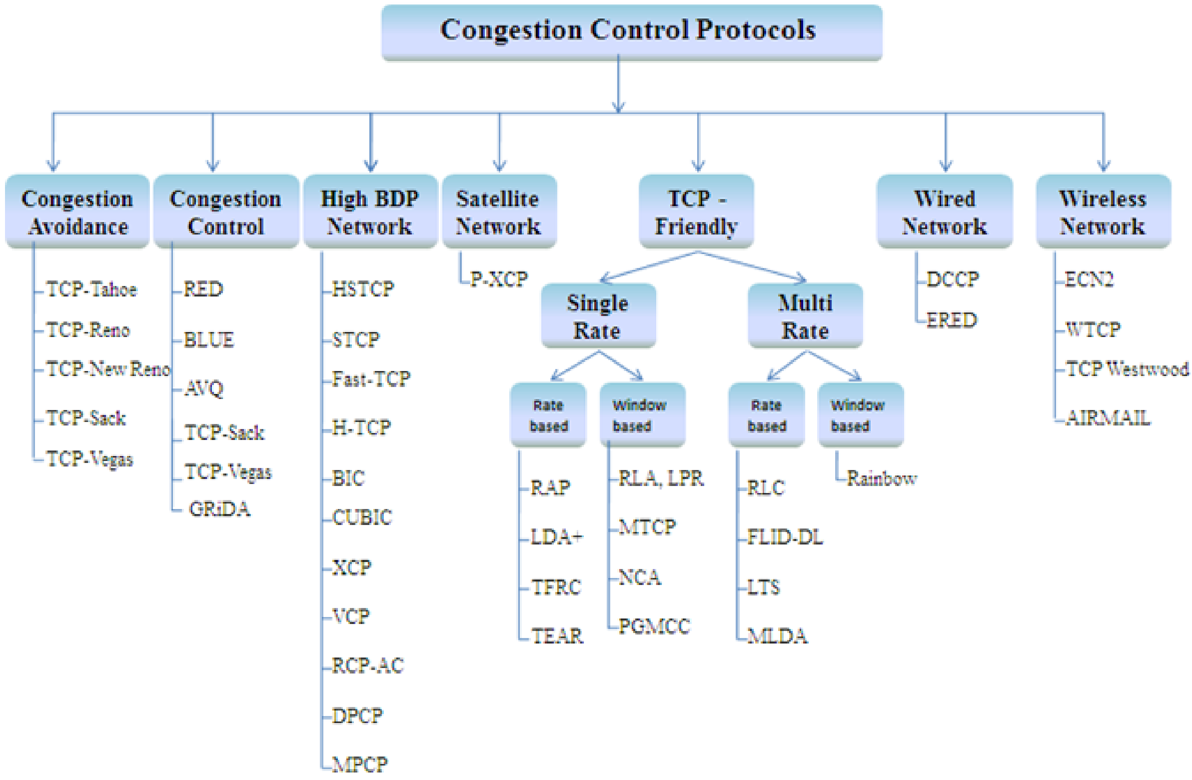

Figure 1: Types of Congestion-control Protocols

d. TCP-SACK[26]

TCP with 'Selective Acknowledgments' is an extension of New-RENO. TCP-SACK works around the problems face by TCP RENO and TCP New-Reno, namely detection of multiple lost packets, and re-transmission of more than one lost packet per RTT. SACK retains the slow-start and fast-retransmit parts of RENO. The biggest problem with SACK is that currently selective acknowledgements are not provided by the receiver.

e. TCP-VEGAS[30]

Vegas is a TCP implementation which is a modification of Reno. It based on the fact that proactive measure to encounter congestion is much more efficient than reactive ones. TCP-VEGAS overcome the problem of requiring enough duplicate acknowledgements to detect a packet loss, and it also suggests a modified slow start algorithm which prevents it from congesting the network. The main thing is that it detects congestion before the packet losses occur. The three major changes induced by Vegas are: New Re-Transmission Mechanism, Congestion avoidance & Modified Slow-start.

2.2 Protocols based of Congestion-Control

a. RED[27]

RED is certainly an improvement over traditional drop-tail queues. In the RED queue management the main idea is to detect incipient congestion early and to convey congestion notification to the end-hosts. While doing this RED allows them to reduce their transmission rates before queues in the network overflow and packets are dropped. To detect congestion RED maintains an exponentially weighted moving average of the queue length. One of the fundamental problems with RED is that they rely on queue length therefore it has an inherent problem in determining the severity of congestion.

b. **BLUE[28]**

A new active queue management algorithm, called BLUE is proposed to solve the problems of RED. BLUE uses packet loss and link utilization history to manage congestion. BLUE performs significantly better than RED, both in terms of packet loss rates and buffer size requirements in the network.

c. AVQ[29]

The AVQ algorithm maintains a virtual queue whose virtual capacity is less than the actual capacity of the link. When a packet arrives in the real queue, the virtual queue is also updated to reflect a new arrival. Packets in the real queue are marked/dropped when the virtual buffer overflows. The virtual capacity at each link is then modified such that total flow entering each link achieves a desired utilization of the link. An important feature of the AVQ scheme is that in the absence of feedback delays the system is maximizes the sum of utilities of all the users in the network.

d. GRiDA

GRiDA is a distributed online algorithm to reduce power consumption in backbone networks. GRiDA is used to selectively switch off links in an Internet Service Provider IP-based network to reduce the system energy consumption. Differently from other approaches, GRiDA does neither require a centralized controller node, nor the knowledge of the current traffic matrix. GRiDA saves energy up to 50% as compared to other existing centralized algorithms.

e. PID

In this case PID design is used with linear gain scheduling and normalized values that works very well under different network traffic conditions. The controller is tuned for the worst scenario and works properly in a wide range of situations. Thus our PID controller is determined only by one parameter, other than traditional PID controller is by three or more. The robust PID congestion controller can outperform the existing controller, such as PI, RED, on keeping the router queue size at the target value.

2.3 High Bandwidth Delay Product (BDP) Network

a. HSTCP[1]

High Speed TCP(HS-TCP) is an enhanced version of TCP that reacts better when using large congestion windows on high-bandwidth, high-latency networks. High Speed TCP focuses specifically on a change to the TCP response function, and its implications for TCP.

b. STCP[17]

The accuracy (AC) is the proportion of the total number of predictions that were correct. It is determined using the equation:

c. FAST TCP[2]

In FAST-TCP a link model is used which captures the queue dynamics when congestion windows of TCP sources change. By using this model FAST TCP is always linearly stable with a single bottleneck link. FAST-TCP extends the existing stability results on homogeneous FAST flows to cases with heterogeneous delays.

d. HTCP[1]

This protocol is used for deployment in high-speed and long-distance networks. In H-TCP window growth function is based on is based on real time. When this protocol is deployed in conventional networks, H-TCP behaves as a conventional TCP-variant.

e. BIC[15]

To solve the RTT unfairness problem, the Binary Increase Congestion control (BIC) protocol is used. BIC supports TCP friendliness and bandwidth scalability. It uses two window size control policies called additive increase and binary search increase.

f. CUBIC[16]

CUBIC extends the work of BIC TCP (Binary Increase Congestion Transmission Control Protocol). The linear window growth function of standard TCP to cubic function is modified in CUBIC**.** To enhance the scalability of TCP in long distance network scenarios, CUBIC is used.

f. XCP[13]

The explicit Control Protocol (XCP) is a multi-level network feedback mechanism for congestion control of Internet transport protocols. XCP is stable and efficient over high bandwidth-delay product paths, while being more scalable to deploy than mechanisms that require per-flow state in routers.

g. VCP

The Variable-structure Congestion-control Protocol(VCP) extends the work of XCP. VCP is a window-based protocol and is designed to regulate the cwnd with different congestion control policies according to the level of congestion in the network. VCP applies MI, AI and MD policies in three regions of congestion known as Low-load, High-load and over-load regions respectively.

h. RCP-AC

In comparison with other congestion control protocols like TCP Reno and XCP, to complete one to two orders of magnitude, Rate Control Protocol(RCP) enables typical Internet-sized flows as fast as possible. But RCP faces some problems. Rate Control Protocol with Acceleration Control(RCP-AC) extends the work of RCP. RCP-AC allows the aggressiveness of RCP to be tuned, enabling fast completion of flows over a broad set of operating conditions.

i. DPCP[20]

Double Packet Congestion-control Protocol(DPCP) extends the work of VCP, in that it utilizes two ECN bits of a pair of packets in order to use the ECN bit a distributed way. In this case, for a given load-factor (LF) the packet that carries LSB of the LF is referred to as LSP and the packet that carries the MSB of the LF is referred to as MSP.

j. MPCP

The Multi Packet Congestion Control Protocol (MPCP) is a novel distributed ECN-based congestion control protocol. By utilizing only two ECN bits MPCP is able to relay a more precise congestion feedback. In MPCP each packet carries two of 2n bits in its ECN bits.

2.4 Satellite Network

a. P-XCP

Explicit Control Protocol (XCP) is a promising transport layer protocol for satellite IP networks. But XCP has some challenges while operating in satellite network. These challenges are low throughput under high link error rate conditions, and output link underutilization in the presence of rate-limited connections. To address the these problems P-XCP protocol is used.

2.5 TCP-Friendly[22]

i. Single Rate

a. RAP

The Rate Adaption Protocol (RAP) is a simple AIMD scheme. In this scheme each data packet is acknowledged by the receiver and the ACKs are used to detect packet loss and infer the RTT.

b. LDA+

Like RAP, LDA+ is essentially an AIMD congestion control scheme, but it uses some interesting additional elements. The Loss-Delay Based Adaption Algorithm (LDA+) relies on the Real-Time Transport Control Protocol (RTCP) feedback messages provided by the Real-Time Transport Protocol (RTP). LDA+ is designed only for unicast communication.

c. TFRC

The TCP-Friendly Rate Control Protocol (TFRC) is designed for unicast as well as multicast communication. TFRC supports additional delay-based congestion avoidance by adjusting the inter packet gap to improve protocol performance in environments that do not fulfill the assumptions of the complex TCP equation, The main importance of TFRC is that is has a relatively stable sending rate while providing sufficient responsiveness to competing traffic.

d. TEAR

TCP Emulation at Receivers (TEAR) is a hybrid protocol because it combines aspects of window-based and rate-based congestion control. In this case sender adjusts the sending rate. TEAR protocol does not directly use the congestion window (cwnd) but calculates the TCP sending rate.

e. RLA & LPR

The Random Listening Algorithm (RLA) extends the work of TCP selective ACK(SACK) by introducing some enhancements for multicast. A TCP-like retransmission scheme with fast recovery is also included in RLA. RLA achieves the statistical long-term fairness. Linear Proportional Response (LPR), is a probabilistic loss indication filtering scheme that is an improvement over the corresponding RLA mechanism. As compare to RLA the LPR scheme achieves better fairness of multicast sessions toward competing unicast sessions. LPR achieves good TCP friendliness in comparison with RLA when combined with the window adjustment mechanism.

f. MTCP

To achieve TCP friendliness, Multicast TCP (MTCP) is a reliable multicast protocol that uses window-based congestion control. In MTCP a logical tree structure is used where the root of the tree is the sender of the data. A parent in the logical tree structure stores a received packet until receipt is acknowledged by all of its children. Upon receiving a packet, a child transmits an ACK to its parent using unicast. The main problem of MTCP is its complexity.

g. NCA & PGMCC

Nominee-Based Congestion Avoidance (NCA) and pragmatic general multicast congestion control (pgmcc) these two protocols shares the same idea. In this approach congestion control and packet repair are treated independent of each other. This approach is used in reliable, as well as for unreliable data transmission. The most challenging aspect of NCA and pgmcc is how to select the group representative.

II.Multi Rate

a. RLC

Receiver-Driven Layered Congestion Control (RLC) protocol is used to dimension the layers so that the bandwidth consumed by each new layer increases exponentially. In case of RLC, granularity at which the rate can be adapted to the network conditions is very coarse and may cause unfair behavior.

b. FLID-DL

To address some of the problems of RLC, Fair Layered Increase/Decrease with Dynamic Layering (FLID-DL).This protocol uses a digital fountain at the source. It introduces the concept of dynamic layering. The FLID-DL protocol extends the work of RLC.

c. LTS

The Layered Transmission Scheme (LTS) is used for the transmission of video. LTS is easy to implement but it suffer from a multitude of drawbacks.

d. MLDA

The Multicast Loss-Delay Based Adaption Algorithm (MLDA) is a congestion control protocol that uses layered multicast. It uses the combination of two protocols that are LDA+ and RTCP reports for the signaling between the sender and the receivers. Thus, it combines sender-based and receiver-based congestion control. The problem of MLDA is the added complexity of the application that has to distribute the data onto the dynamic layers.

e. Rainbow

Rainbow is a window-based congestion control scheme which is used for the reliable transfer of bulk data. In this case the data is encoded using a digital fountain. The main idea behind Rainbow is that receivers individually request the transmission of each data packet

2.6 Wired Network

a. Enhanced RED

In this approach ERQD algorithm is used for congestion avoidance in wired networks. The main idea behind this algorithm is to optimize the value of the average size of the queue used for congestion avoidance and to consequently reduce the total loss of packets at the queue and also reduces the Queue delay. This algorithm reduces the number of packet losses at the gateway and also reduces the queue delay.

2.7 Wireless Network

a. DCCP

DCCP, provide an efficient congestion control mechanism for heterogeneous wired-cum-wireless networks by using Congestion Control Identification (CCID) framework. DCCP evaluates a congestion control mechanism that implicitly discriminates congestion and wireless losses.

b. ECN2

Some of the protocols in network do not work well in wireless network because they take packet losses or timeout as the signal of congestion. The ECN2 protocol is based on expanded ECN mechanism to respond packet losses in wireless environment.

c. WTCP[10]

WTCP is a reliable transport protocol that addresses rate control and reliability over commercial WWAN networks such as CDPD. WTCP uses only end-to-end mechanisms and performs rate control at the receiver, and uses inter-packet delays as the primary metric for rate control. WTCP performs better than other protocols like TCP-RENO.

d. TCP_Westwood[11]

TCP Westwood (TCPW) is a sender-side modification of the TCP congestion window algorithm. TCPW improves upon the performance of TCP Reno in wired as well as wireless networks. An important distinguishing feature of TCP Westwood with respect to previous wireless TCP "extensions" is that it does not require inspection and/or interception of TCP packets at intermediate nodes.

e. AIRMAIL[8]

Asymmetric Reliable Mobile Access In Link-layer (AIRMAIL) is a link-layer protocol for indoor and outdoor wireless networks. AIRMAIL is asymmetric to reduce the processing load at the mobile.

CONCLUSION

This paper discusses various congestion control protocols in network. Designing an efficient congestion control protocol which solves all problems of congestion is very difficult. Hence a survey of different congestion-control protocols, comparing the various features is absolutely essential to come up with new proposals for congestion–control in network. The performance of congestion-control protocols depend on various parameters. Thus this paper has come up with an exhaustive survey and comparison of different classes of congestion-control protocols.

REFERENCES

[1] D. Leith and R. Shorten, "H-TCP: TCP for high-speed and long-distance networks," in *Proc. PFLDNet*, Feb. 2004.

[2] C. Jin, D. Wei, and S. Low, "FAST TCP: Motivation, architecture, algorithms, performance," in *Proc. IEEE INFOCOM*, 2004, vol. 4, pp.2490–2501.

[3] Y. Xia, L. Subramanian, I. Stoica, and S. Kalyanaraman, "One more bit is enough," in *Proc. ACM SIGCOMM*, Aug. 2005, pp. 37–48.

[4] H. Balakrishnan, V. N. Padmanabhan, S. Seshan, and R. H. Katz, "A comparison of mechanisms for improving TCP performance over wireless links," *IEEE/ACM Trans. Netw.*, vol. 5, no. 6, pp. 756–769, Dec.1997

[5] M. Hu and B. Liu, "Mining and summarizing customer reviews," in Proc.10thACM SIGKDD Int. Conf. Knowl. Discov. Data Mining, 2004, pp.168–177.

[6] A. Bakre and B. R. Badrinath, "I-TCP: Indirect TCP for mobile hosts," in *Proc. 15th ICDCS*, Vancouver, BC, Canada, May 1995, pp. 136–143.

[7] Xiaolong Li, Homayoun Yousefi'zadeh,"Analysis, Simulation, and Implementation of VCP: A Wireless Profiling," IEEE/ACM Trans. Netw., vol. 18, no. 5, Oct.2010

[8] C. Parsa and J. Garcia-Luna-Aceves, "Improving TCP performance over wireless networks at the link layer," *Mobile Netw. Appl.*, vol. 5, no. 1, pp. 57–71, Mar. 2000.

[9] I. A. Qazi and T. Znati, "On the design of load factor based congestion control protocols for next-generation networks," in *Proc. of the IEEE INFOCOM 2008*, Apr. 2008.

[10] N. Vasic, S. Kuntimaddi, and D. Kostic, "One Bit Is Enough: a Framework for Deploying Explicit Feedback Congestion Control Protocols," in *Proc. of the First International Conference on COMmunication Systems and NETworkS (COMSNETS)*, Jan. 2009.

[11] M. Goutelle, Y. Gu, and E. He, "A Survey of Transport Protocols other than Standard TCP," 2004, https://forge.gridforum.org/forum/forum.php?forum id=410.

[12] L. Xu, K. Harfoush, and I. Rhee, "Binary Increase Congestion Control (BIC) for Fast Long-Distance Networks," in *Proc. of the IEEE INFOCOM*, 2004.

[13] I. Rhee and L. Xu, "CUBIC: A New TCP-Friendly High-Speed TCP Variant," in *Proc. of the PFLDNet'05*, Feb. 2005.

[14] D. Katabi, M. Handley, and C. Rohrs, "Congestion Control for High Bandwidth-Delay Product Networks," in *Proc. ACM SIGCOMM*, Aug. 2002.

[15] H. Yousefi'zadeh, X. Li, and A. Habibi, "An End-to-End Cross-Layer Profiling Study of Congestion Control in High BDP Wireless Networks," in *Proc. of the IEEE WCNC, 2007*, Mar. 2007.

[16] Stevens W. TCP Slow Start, Congestion Avoidance, Fast Retransmit, and Fast Recovery Algorithms" RFC 2001, 1997.

[17] V. Hatzivassiloglou and K. R. McKeown, "Predicting the semantic orientation of adjectives," in Proc. 8th Conf. Eur. Chap. Assoc. Comput. Linguist, Morristown, NJ: Assoc. Comput. Linguist. 1997, pp. 174–181.

[18] Wu-chang Feng, Kang G. Shin, Dilip D.Knadlur, Debanjan Saha. The BLUE active queue management algorithms. IEEE/ACM Transactions on Networking, 2002,10(4):513-528

[19] Athuraliya S., Low S. H., Li V. H., and et al. REM: Active Queue Management, IEEE Network, 2001, 15(3): 48-53.

[20] Srijith K.N., Jacob L., Ananda A.L.TCP Vegas-A: Improving the performance of TCP Vegas, Computer Communications,2005,28(4):429-440

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