



Summary of the Congestion Control and Congestion Avoidance Fundamentals

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Interaction Goals

- **What is Congestion?**
- **Congestion Control**
- **Difference between Flow Control and Congestion Control**
- **Congestion Control Algorithms**
- **Congestion Avoidance**
- **Congestion Avoidance Algorithms**
- **Recommended Readings**

Congestion Control:

- Types of Congestion Control Schemes:
 - Open Loop Congestion Control Schemes
 - Traffic Filtering Schemes (use accept / reject rules)
 - Traffic Scheduling Schemes
 - Closed Loop Congestion Control Schemes
 - Uni-Variable Feedback based schemes
 - Multi-Variable Feedback based schemes

Congestion Control ...

- Congestion Metrics:
 - Average / Mean Queue Length
 - Average number or percentage of lost / discarded packets
 - Number of retransmitted packets those had to be sent again because of Transmitter's Time-out
 - Average / Mean Delay in Packet Delivery

Congestion Control ...

Congestion Control Strategies:

- Congestion control by regulating admission of Packets / Cells
- Congestion control by regulating traffic based on traffic-type / traffic-rate (packet rate / cell rate / bit rate etc.) analysis
- Congestion control by admission-time resource reservation

Congestion Control ...

Congestion Control Strategies ...

- Congestion control by threshold monitoring and message passing
- Congestion control by preferential restraint **(in research stage)**
- Congestion control by Ostrich algorithm **(debatable)**
- Congestion control by supervised blocking / rerouting **(under investigation)**

Congestion Control ...

The Anticipatory Buffer Allocation Scheme:

- In this scheme, which is particularly suitable for Virtual Circuit Subnets, congestion can be effectively controlled / avoided by estimating the optimal buffering needs of the Switches and allocating this buffer capacity to Virtual Circuits on anticipatory / pro-active basis.
- It is a variation of pre-allocation scheme since it allocates estimated capacity in advance.
- This scheme differs from the standard VC establishment scheme in the way that in the latter no buffer-space allocation is reserved at the Switches by the call-request packet. Also, no permanent buffer allocation is done a-priori, in the latter scheme.

Congestion Control ...

The Anticipatory Buffer Allocation Scheme...

- This scheme may be implemented using many different protocols including the Sliding Window and Stop-and-Wait protocols.
- Choice of a protocol, in any case depends on the desired throughput, available buffer capacity and the associated price.
- However, for the VCs that may not, at an average, have adequate traffic so as to effectively use a sizeable chunk of such pre-allocated buffer-space, the economics may not be favourable.
- Moreover, this is, in effect, a Congestion Avoidance Scheme rather than an adaptable Congestion Control Scheme.

Congestion Control ...

The Anticipatory Buffer Allocation Scheme...

- A possible variation of this scheme could be, as suggested in the beginning, a dynamic allocation scheme that is proactive by nature and that, by using some adaptive / statistical buffering need-determination algorithm, estimates / anticipates the required buffer size and if available, allocates the VC in question.
- The primary difference here is that the call request packet need not ask for any buffer reservation. Moreover, this allocation may be done after the establishment of the VC. This scheme duals as an Avoidance as well as a Control scheme since if invoked during VC establishment, it provides avoidance whereas if triggered by anticipation of congestion, could simply reduce the chances of its building up.
- However, this solution is relatively complex to implement and has a potential of occasional misfire.
- Both of the discussed solutions, therefore, do not prove attractive.

Congestion Control ...

'Arbitrary Packet Rejection-based' / 'Reject-on-Getting-Full' Congestion Control Scheme

- This scheme is the simplest of all congestion control schemes.
- It controls further building up of congestion just by dropping any further packets reaching the node in question, entirely arbitrarily, without any learned analysis. As a result, even ACKs might get rejected and cause a series of unwarranted problems.
- This scheme requires absolutely no buffer reservation / advance allocation, in complete contrast to the earlier scheme. A variation of this scheme is called the Leaky Bucket Algorithm.
- This too is not an attractive solution because of obvious potential for creating deadlocks.

Congestion Control ...

Selective Packet Rejection based Congestion Control Scheme

- This scheme is the modified version of the previous congestion control schemes.
- It controls further building up of congestion by selective dropping of packets reaching the node in question.
- The choice of selective acceptance / rejection is governed by a set of rules.
- This scheme, like its predecessor, requires absolutely no buffer reservation / advance allocation.

Congestion Control ...

Permit-based / Token-based / Isarithmic Congestion Control Scheme:

- As the name itself suggests, this algorithm uses a Permit / Token based admission control with respect to entry to a node.
- Any sender node willing to transmit 'n' packets to a receiving node is first required to capture 'n' Tokens / 'Permit for sending 'n' packets'. If only one Token is captured, only one packet can be transmitted.
- The number of total Tokens available is usually kept constant; and as result, this scheme ensures a predictable constant traffic, without any loss of packets.
- A variation of this algorithm is known as the Token Bucket Algorithm.

Congestion Control ...

The Choke Packet Scheme of Congestion Control:

- One of the possible ways to control congestion is to cut down the incoming traffic to a node by informing the originator of the traffic that a state of congestion has occurred and the originator should cut down its packet transmission rate intended to reach / pass through this receiver.
- This scheme uses just that! It makes use of what is termed as 'Choke Packet' for indicating to the originator about the congestion and expects it to cut down its transmission rate by a pre-defined percentage.

Congestion Control ...

The Choke Packet Scheme of Congestion Control ...

- What exactly happens is this! The various Routing nodes periodically run a routine for estimating the state of utilization of their one or more output lines and compute an index that could, on crossing a certain threshold value, normally suggest that a state of congestion is about to arrive or has arrived.
- Whenever this threshold value is reached, the congestion control routine gets fired.

Congestion Control ...

The Choke Packet Scheme of Congestion Control ...

- Once this routine swings into action, any packet other than an ACK that arrives at this node intending to be forwarded on any one of the congested output lines is blocked and a special packet called the “Choke Packet” is constructed by extracting the originating node’s address from the Sender’s Address field of the packet that has been blocked.
- The original packet itself is tagged / included as payload (to the generated header with a bit set) so as to help the originator learn so that it does not generate traffic any further / more than the default cut-down rate thereafter for a stipulated period of time.

Congestion Control ...

The Choke Packet Scheme of Congestion Control ...

- Many variations of the Choke Packet-based scheme exist. However, most of them have potential to generate further network congestion due to a lot of possible choke-packet traffic.
- One such possible solution is the Hop-by-Hop Choke Packet-based scheme of congestion control. This scheme has a special feature of helping in cutting down the incoming traffic systematically and gradually by informing every intermediate Router along the way of the Choke Packet. Thus, in effect, at every hop, the scheme succeeds in immediately initiating reduction in traffic towards the congested node; rather than allowing the flow to continue until the Choke Packet reaches its destination and an action is taken.

Congestion Control ...

- Deadlock due to congestion: There exists an extreme effect of failure to timely control of congestion! That's the Transmission Deadlock / Lock-up State.
- Such deadlocks can be of several types including Direct Store-and-Forward Deadlock / Lockup and Indirect Store-and-Forward Deadlock / Lockup.
- A well-known solution to such deadlocks was suggested long back by Merlin and Schwietzer that involved use of a specially constructed directed graph showing Buffers as nodes and arcs connecting a pair of buffers in the same or adjacent router.
- Several other solutions have been proposed since then.

Recommended Readings:

- S. Keshav: An Engineering Approach to Computer Networking, AWL, 1997.
- A. S. Tanenbaum: Computer Networks, Fourth Edition, PHI, 2006.
- C. Huitema: IPv6, Second Edition, Prentice-Hall PTR, 1998.
- U. D. Black: Computer Networks, Second Edition, PHI, 1993.
- D. Bertsekas and R. Gallager: Computer Networks, Second Edition, PHI, 1992.
- G. R. McClain (Ed.): Handbook of Networking and Connectivity, AP Professional (Academic Press), 1994.

Recommended Readings ...

- RFC 1009 (Requirements for Internet Gateways)
- RFC 1254 (Gateway Congestion Control)
- RFC 1360 (Official Protocol Standards of the Internet Architecture Board)
- RFC 1124 (Policy Issues in Interconnecting Networks)
- RFC 1125 (Policy Requirements for Inter-Administrative Domain Routing)
- RFC 781 (IP Timestamp)
- RFC 791 (IP)
- RFC 815 (IP Datagram Reassembly)
- RFC 1042 (IP over IEEE 802.3)
- RFC 1011 (Official IP)

Recommended Readings ...

- RFC 1883 (IPv6 Specification)
- RFC 1825 (IP Security Architecture)
- RFC 1826 (IP Authentication Header)
- RFC 1827 (IP Encapsulation Security Payload)
- RFC 1828 (IP Authentication using MD5)
- RFC 1175 (FYI : A very useful reference-list on Internetworking related information)
- RFC 1208 (Glossary of Networking Terms)
- Smoot Carl-Mitchell & John S. Quarterman: Practical Internetworking with TCP / IP and UNIX, Addison-Wesley, Reading, 1993. (This book does not really discuss the IPv6. This however, helps the reader to take a look at the pre-IPv6 days and realize the wisdom of evolution of the IP.)

Recommended Readings

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- Larry Hughes: Introduction to Data Communication: A Practical Approach, Narosa Publishers, 1997.
- Prakash C. Gupta: Data Communications, PHI, 1996.
- A. Shah: FDDI: A High Speed Network, PTR Prentice Hall, 1994.
- M. R. Tolhurst (Ed.): Open System Interconnection, Macmillan, 1988.
- William Stallings: Data and Computer Communications, Fifth Edition, PHI, 1998.

Recommended Readings ...

- D. Comer: Internetworking with TCP / IP , Vol..-1, PHI, 1995.
- D. Comer & D. L. Stevens: Internetworking with TCP /IP, Vol.. 2-3, PHI, 1994, 1993.
- W. Buchanan: Advanced Data Communication and Networks, Chapman & Hall, London, 1997.
- Uyles D. Black: TCP / IP & Related Protocols, Second Edition, McGraw-Hill, N. Y., 1995.
- RFC 1519 (CIDR)
- RFC 1997 (BGP community attribute)
- Bassam Hallabi: Internet Routing Architectures, Cisco Press, New Riders Publishing, 1997.
- RFC 904 (Exterior Gateway Protocol)