

A BIBLIOGRAPHY ON PERFORMANCE ISSUES IN ATM NETWORKS

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ABSTRACT

The Asynchronous Transfer Mode (ATM) is the transport mode of choice for B-ISDN. In order for high speed networks to become a reality, a number of performance issues has to be resolved. In recent years, there has been a growing interest in the literature in developing performance models to explore a wide range of performance problems varying from understanding the performance of a switch architecture to implementing efficient congestion control mechanisms and light weight transport protocols. In this paper, we briefly discuss various performance problems that arise in ATM networks and provide a bibliography of related papers reported in the literature.

PERFORMANCE ISSUES IN ATM NETWORKS

The introduction of highly reliable fiber systems into the access network provides the high bandwidth necessary for future ISDN services, such as video, voice, and large file transfers. These services will have different performance requirements for end to end delay and packet loss. Furthermore, all connections will be statistically multiplexed at the physical layer, making it a complex task to achieve high utilization of network resources while sustaining the required Grades of Service (GOS) for all applications.

The Asynchronous Transfer Mode (ATM) is the transport mode of choice for Broadband-ISDN. ATM is capable of multiplexing large number of connections efficiently. Basic transport unit in an ATM network is a 53-byte ATM cell which consists of 48 bytes of information field and 5 bytes of header. ATM is used on top of a physical layer (i.e. SONET). Above the ATM layer is the ATM Adaptation Layer (AAL) which supports connections between ATM and non-ATM interfaces. At the transmitting end, information units are segmented and bits are collected into ATM cells. At the receiving end, cells are reassembled to form the information unit or read out. User and control services will run above the AAL.

Several performance issues need to be resolved before ATM networks become a reality. In recent years, there has been a growing interest in the literature in developing performance models of ATM networks to explore a wide range of performance problems varying from understanding the performance of a switch architecture to implementing efficient congestion control mechanisms and light weight transport protocols. In this paper, we briefly discuss various issues related to performance of ATM networks and provide a bibliography of related papers reported in the literature.

SWITCH ARCHITECTURES AND THEIR PERFORMANCE

In recent years, various switch architectures have been proposed in the literature. The evaluation of a switch architecture may be based on a weighted average of a number of performance characteristics that include design maturity, hardware complexity, diagnostic complexity, growth potential, packet sequencing, broadcast capability, network speed up requirements, throughput, and latency.

For presentation purposes, the proposed switch architectures can be classified into two categories: shared medium, i.e. bus, and multi-stage interconnection networks, i.e. cross bar and Banyan based multi-stage interconnection networks.

Shared medium switches naturally lead themselves to broadcasting. They are less complex to build than multi-stage interconnection networks, and highly reliable. Their performance characteristics are relatively easy to obtain. However, the number of ports that a shared medium switch can support is limited to a relatively small number. On the other hand, multi-stage interconnection networks have the desirable feature of self routing and their modular architecture allows excellent growth potential. They require complex fault

detection procedures and they have poor broadcasting capabilities. The interested reader may refer to [29] and [13] for a survey of switch architectures proposed in the literature for ATM and high speed networks.

In general, the performance analysis of a proposed switch architecture is not an easy task. This is mainly due to the fact that a switch consists of a large number of queues that interact with each other in a fairly complicated manner. In view of the complexity of these systems, simulation may not be an efficient modeling technique as long run times may be required to estimate its performance characteristics. Numerical techniques are limited to the analysis of switch fabrics with a small number of ports. An alternative way to estimating the performance metrics of a switch fabric is to use queueing theory. A switch is first represented by a network of queues and then analyzed approximately using the notion of decomposition. That is, the queueing network under consideration is decomposed into individual queues and each queue is analyzed in isolation.

Until recently, such queueing networks have been developed under rather unrealistic system assumptions: i.e., with arrival processes that do not necessarily characterize the source characteristics in this environment and with independent uniform traffic pattern in which all output ports are equally likely to be chosen by an arriving cell. Currently, there is a growing interest in the literature in developing methodologies to analyze ATM switch architectures approximately under more realistic assumptions.

TRAFFIC SOURCE CHARACTERIZATION AND STATISTICAL MULTIPLEXING

Traffic that will be carried out by ATM networks can be distinguished into the following two types: Continuous Bit-Rate (CBR) and Variable Bit Rate (VBR). In CBR, there is an uninterrupted flow of digital information generated at a constant bit rate, i.e. video source coding producing constant bit rate, or, voice where silence periods are transmitted. In VBR, information is generated at variable rates and the mean rate at which information is generated is less than its maximum rate. This type of traffic arises in services such as bulk file transfers, encoded video, and voice transmission where the silence periods are not transferred.

The characterization of the arrival processes in this environment is still an open issue. The source traffic is generally referred to as bursty traffic. However, there is no common definition of burstiness agreed upon in the literature. Unfortunately, for the time being, there are no comprehensive real life measurements which will permit us to establish what traffic models are realistic for what types of applications.

One type of characterization used in the modeling studies of ATM networks is the two state on/off model. In this model, a source is active for some period of time, referred to as the busy period. A busy period is followed by a silence period in which no activity takes place. The two periods alternate continuously. This simple model captures the basic idea that a VBR source may either be active or inactive. It also implies that there is no correlation between the successive interarrival times. More complex models, such as Markov Modulated Processes, allow the introduction of correlation. In these models, the rate at which arrivals occur depends on the state of the underlying Markov chain.

All models developed in the literature assume that users can provide the data needed to determine their parameters. The source characteristics to be defined in this environment may at least include the average bandwidth, peak bandwidth, and burst length. However, users may not know the values of the required parameters or may be unwilling to provide them. One possible solution to this problem is to categorize all available service levels to a number of service classes. Then, the user would request a specific service class. The feasibility of using service classes and the criteria to be used in defining them have not yet been addressed satisfactorily in the literature.

In ATM networks, connections are statistically multiplexed at the physical link. In order to model a link, one has the option to model each bursty source separately. However, this may lead to an intractable model, particularly as the number of connections multiplexed on a link increases. An alternative is to superpose all connections into a single or a few number of sources, thereby reducing the dimensionality of the problem. However, it is in general difficult to characterize the superposition process. There are a few approximation

algorithms reported in the literature to obtain the parameters of the superposed process. Another way of analyzing a single queue with multiple arrivals is the fluid flow approximations. This technique appears to be a promising method and it is fairly accurate, particularly when used to characterize voice sources. One disadvantage of the method is that it is not sensitive to the distribution of the arrival process during the busy period.

The proposed algorithms do not yet satisfactorily address the problem and further research is needed in characterizing the superposed processes in ATM networks.

ROUTING

The Virtual Path Identification (VPI) and the Virtual Circuit Identification (VCI) fields of ATM header are used for cell routing. The VPI provides an explicit path while VCI provides an explicit circuit identification for the cell. A virtual path is a set of virtual circuits. At least one route is defined for each virtual path in the network. Accordingly, there is no need to update the routing table for each call setup request as at least one path is guaranteed to exist.

Multi-stage interconnection networks have been proposed as switch fabrics in high speed networks. The self routing capability of these switches require that its output port address must be known before a cell can be forwarded through the switch. However, this information is not carried with the cell. Accordingly, based on its VPI, a table lookup needs to be performed to determine the output ports of arriving cells. As this operation takes place every time a cell arrives at an input port, efficient means of table look up needs to be developed to handle incoming traffic. The identifier of the path can be used as an index in these routing tables. Updates to this table will most likely happen in a distributed fashion, since static routing tables can not cope with failures in the network or with topology changes. The process of updating the routing tables in this environment has not been fully explored in the literature.

A path from source to destination must be decided at connection request time. Most algorithms determine the route by choosing the 'shortest' or 'least expensive' path. To the best of our knowledge, there is no study in the literature to define the cost of a path for ATM networks. In traditional low speed networks, the cost was mainly defined as the mean end-to-end delay. In case of ATM, however, it may be preferable to sacrifice delay for other objectives such as, the variance of the end-to-end delay, or, the probabilities of rejecting connection requests and losing cells. Most routing algorithms for traditional networks are variants of the shortest path algorithms proposed by Ford/Fulkerson and Dijkstra. The first is an inherently distributed algorithm, with very small requirement of knowledge on the network topology (i.e. immediate neighbors only) while the second algorithm requires relatively larger memory (complete knowledge of the network topology at each node is required) and requires the definitions of protocols to keep the topology information up to date. Both algorithms exhibit the routing table looping problem. That is, a packet 'sees' inconsistent path information at various nodes along its path due to the fact that update messages are not received by all nodes simultaneously. The problem is further pronounced in the case of ATM networks where a burst of packets may be forced to loop in the network causing a major performance degradation. Routing in ATM networks remains to be an open issue and further research is needed to explore various alternative routing strategies.

CALL ADMISSION

Since a connection has to be established before any transmission occurs, a process that checks the requirements of the connection while taking into account the current state of the network is needed. Call admission procedures decide whether a new connection request should be accepted or rejected. The establishment of a connection over a path from its source to destination would mean that all nodes along the path can provide the requested GOS to the connection without degrading the GOS agreed upon for connections already established in the network.

In general, the decision to accept or reject a new connection request requires the analysis of the transmission links along the connection's route. The exact solution to the problem is not feasible to obtain, particularly in real time. Algorithms proposed in the literature use queueing theory to decompose a given path into individual transmission links and analyze each link in isolation. Even in this case, the analysis of a single queue may not be tractable due to large number of connections established over that link. As discussed above, one can use the superposed process or the fluid flow model to approximately obtain the performance metrics of the link to be used in decision making. Another alternative is to determine the incremental bandwidth needed by the new connection request, given the source characteristics of the new connection together with the amount of bandwidth already allocated on the link for established connections. Then, if the total bandwidth including the new connection is less than some pre-determined fraction of the link capacities then the connection request is accepted, otherwise it is rejected.

To determine the incremental bandwidth required by the new connection request, one approach is to analyze each connection independent of each other in isolation. That is, if a connection is input to a link with a finite buffer capacity, what should the transmission rate be for this connection to achieve a desired GOS. However, analyzing each connection in isolation may result in an over controlled network.

The problem is further complicated due to the fact that traffic characteristics of sources may change as the traffic stream goes through a number of nodes, i.e. the traffic may become less bursty at the downstream nodes than it is at the source node. Taking the effect of statistical multiplexing into account in the call admission procedures require characterizing the departure processes of the upstream nodes and use them as the arrival processes to the downstream nodes. However, using the original source characteristics at every node is the current practice in the procedures developed in the literature. Yet, ignoring the smoothing effect of the network would result in an over controlled network thereby under utilizing the network resources.

Further research is needed in developing call admission procedures that are fairly accurate, take into consideration the network smoothing, and can be executed in real time.

CONGESTION CONTROL AND SOURCE POLICING

Call admission may not be sufficient to control network congestion as users may deviate from their negotiated terms. For example, it may not be possible for a user to accurately specify its source characteristics, the user's equipment may mal-function, or users may purposefully attempt to use more bandwidth than negotiated originally. Accordingly, congestion control is required to ensure that GOS is met for each connection and that the network resources are fairly allocated.

Congestion control schemes can be classified into two categories: Reactive and Preventive. Reactive schemes, utilized in existing low speed networks, instruct the sources to throttle their traffic flow through feedback mechanisms. However, as transmission speeds increase propagation delays become significant causing the feedback mechanisms to become ineffective, i.e. by the time the feedback reaches the source and the control is triggered, it is usually too late to react. An alternative is to prevent the network from reaching unacceptable levels of congestion by utilizing a bandwidth enforcement mechanism. Preventive control scheme use policing functions to protect the network against congestion by forcing the traffic to conform to the parameters negotiated at the call connection phase. The most popular policing function is the Leaky Bucket. In this scheme, a counter is incremented each time a cell is generated by the source and decremented periodically at a suitable leaky rate. A cell arriving at a time when the counter has reached a given threshold is considered to be in violation with the negotiated terms. Depending upon the implementation, the violating cell is dropped, buffered, or it is marked as in violation and sent to the network. Allowing marked cells to enter the network increases the utilization of network resources. However, these cells need to be treated differently at the intermediate nodes to make sure that they do not degrade the GOS of other connections. The two parameters that need to be set for the leaky bucket are the threshold value and the

leaky rate. The leaky rate can be set to monitor the average or peak bandwidth, but not both. The threshold value, on the other hand, can not be set easily and its value has a major impact on the GOS offered to the call. In particular, larger threshold values may be needed in order to obtain the required cell loss probability. This, however, implies that it will take a long time to detect that a connection is violating its negotiated bandwidth. Other bandwidth enforcement mechanisms proposed in the literature include the jumping window, the moving window, and the exponentially weighted moving average. Two objectives that can be used to evaluate different proposals are that a call congestion control mechanism should i) be transparent to the source when the source is within its negotiated contract, and, ii) filter the excessive traffic when the source exceeds its contract. Comparisons between various congestion control mechanisms have not been carried out satisfactorily in the literature.

FAIRNESS IN ATM NETWORKS

Fairness means that well behaved users are not harmed by abusive users, and that under congestion the network divides its resources among connections in a controlled way. As mentioned above, in ATM networks, cells belonging to a connection that violates its contract may be sent to the network to achieve better resource utilizations. To guarantee that these marked cells do not degrade the quality of service of other connections that stay within the negotiated terms, marked cells may be discarded within the network. Various discarding mechanisms that define the rules for discarding have been proposed in the literature. From the performance point of view, one discarding mechanism is better than another one if it produces higher throughput than the other while ensuring that quality of service provided to unmarked cells is not degraded. Implementation complexities of such mechanisms are also of importance. Further research is needed to obtain and compare the performance characteristics of various discarding mechanisms proposed in the literature under realistic arrival processes.

Fairness in traditional low speed networks is achieved by serving virtual circuits according to some type of round robin discipline, rather than first in first out. In case of ATM networks, link bandwidths are shared between a number of virtual paths and the bandwidth allocated to a virtual path is shared by several virtual circuits. How to achieve fair sharing of resources between virtual paths is currently an open issue. The problem is more complicated at the virtual circuit level as the processing power required to achieve fairness for virtual circuits may be prohibitive in this environment unless proposed functions can be implemented in hardware. Further research is needed to explore the issue of fairness in ATM Networks.

TRANSPORT PROTOCOLS

As technology advances rapidly to meet the need for high speed communications, the bottleneck of communications networks has been moved from the transmission media to the communications processors. The throughput and end to end delay in a high speed network are limited by the processing power of the transmitting and receiving nodes, since very little processing can be done at the intermediate nodes. Accordingly, either already existing protocols must be optimized or new protocols that exploit the characteristics of high speed networks need to be developed. Adopting an updated version of an existing protocol can significantly reduce the amount of time required to standardize a transport protocol, whereas a new protocol would easily take up to six years or more to standardize. The improvements to existing protocols may be achieved by reducing their overheads, for example, by

1. *Optimization of Execution Path,*
2. *Use of Bigger Packet Sizes,* to reduce the time spent on packet specific operations
3. *Packet Grouping,* to achieve group acknowledgements and group-oriented control information.

4. *Better Dynamics of the Protocol*, i.e., periodic exchange of state information
5. *Alignment of Fields to Word Boundaries*,
6. *Placement of Control Information to Header or Trailer*,
7. *Unique Use of Fixed Length Control Fields*,
8. *Streamlining of Functions*,
9. *Streamlining of End-to-End Operations*,

The interested reader may refer to [171] for a survey of lightweight protocols proposed in the literature for high speed networks including Datakit, Delta-T, NETBLT, OSI/TP4, TCP, VMTP, and XTP.

ERROR CONTROL

Error control is a technique that allows a protocol to recover from lost or damaged Protocol Data Units. In traditional low speed networks, error control has been handled primarily by the data link protocols, which permits two adjacent nodes in an end to end path to locally detect and recover from message loss or corruption along the link that joins them. As the link speeds increase, the time to do error recovery decreases. The problem is further complicated due to large propagation delays compared with the cell transmission times in ATM networks, i.e. number of cells that can be in transit over a link increases as the propagation delay/link speeds increase. Therefore, a more promising approach to error recovery is to do it end to end. Despite the importance of the issue, error control in ATM networks has not been fully addressed in the literature. In particular, in contrast to the numerous studies of cell level models reported, there are very few studies of burst/packet level models.

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REFERENCES

General

1. CCITT Study Group XVIII, "WP XVIII/8 - Report of meeting," Temporary Document no. 16 (Plenary), Geneva, Switzerland, June 1989.
2. CCITT Study Group XVIII, "Meeting Report of Sub-Working Party 8/1 ATM," Temporary Document no. 14-E (Plenary), Geneva, Switzerland, June 1989.
3. CCITT Study Group XVIII, "Report of SWP-8/4 network specs," Temporary Document no. 18 (Plenary), Geneva, Switzerland, June 1989.
4. CCITT Study Group XVIII, "ATM Layer Specification for B-ISDN," Draft Recommendation I.361, Geneva, Switzerland, January 1990.
5. A. Albanese, H. E. Bussey, S. B. Weinstein and R. S. Wolf, "A Multi-Network Research Testbed for Multimedia Communication Services," *ICC '91*, pp. 86-91, 1991.
6. J. J. Bae and T. Suda, "Survey of Traffic Control Schemes and Protocols in ATM Networks," *Proc. IEEE*, vol. 79, no. 2, pp. 169-189, February 1991.
7. G. Gallassi, H. Hofstetter and T. Worster, "Teletraffic Studies on ATM in the Broadband Local Network Technology RACE Project," *ITC-13*, pp. 41-46, 1991.
8. S. Kano, K. Kitami and M. Kawarasaki, "ISDN Standardization," *Proc. IEEE*, vol. 79, no. 2, pp. 118-124, February 1991.
9. L. Kleinrock, "ISDN - The Path to Broadband Networks," *Proc. IEEE*, vol. 79, no. 2, pp. 112-117, February 1991.

10. R. O. Onvural and H. G. Perros, Performance Issues in High Speed Networks, Book of Speakers, Telecom'91, Zurich, Sep. 1991
11. R. O. Onvural, Performance Characteristics of ATM Networks, Proc. ICC'92, Chicago, 1992
12. F. Sammartino and D. Blacketter, "Desktop Multimedia Communications - Breaking the Chains," *ICC '91*, pp. 73-77, 1991.

Switch Architecture and Performance

13. H. Ahmadi and W. E. Denzel, "A Survey of Modern High-Performance Switching Techniques," *IEEE JSAC*, vol. 7, no. 7, pp. 1091-1103, September 1989.
14. T. C. Banwell, et al., "Physical Design Issues for Very Large ATM Switching Systems", *IEEE JSAC*, 9-8, pp. 1227-1237, 1991
15. J. S.-C. Chen and T. E. Stern, "Throughput Analysis, Optimal Buffer Allocation, and Traffic Imbalance Study of A Generic Nonblocking Packet Switch," *IEEE JSAC*, vol. 9, no. 3, pp. 439-449, April 1991.
16. J. S.-C. Chen and T. E. Stern, "Throughput Reduction due to Non-Uniform Traffic in a Packet Switch with Input and Output Queueing," *ICC '91*, pp. 413-417, 1991.
17. I. Cidon, J. Derby, I. Gopal and B. Kadaba, "ATM Fast Packet Switching: A Critique," *Manuscript*.
18. M. Decina, P. Giacomazzi and A. Pattavina, "Shuffle Interconnection Networks with Deflection Routing for ATM Switching: the Open-Loop Shuffleout," *ITC-13*, pp. 27-34, 1991.
19. A. Descloux, "Stochastic Models for ATM Switching Networks," *IEEE JSAC*, vol. 9, no. 3, pp. 450-457, April 1991.
20. X. Jiang and J. S. Meditch, "Integrated Services Fast Packet Switching," *GLOBECOM '89*, pp. 1478-1482, 1989.
21. Y. M. Kim and K. Y. Lee, "PR-Banyan: A Packet Switch with a Pseudo Randomizer for Nonuniform Traffic," *ICC '91*, pp. 408-412, 1991.
22. S.-Q. Li, "Performance of a Non-Blocking Space-Division Packet Switch With Correlated Input Traffic," *GLOBECOM '89*, pp. 1754-1763, 1989.
23. S. C. Liew and K. W. Lu, "Comparison of Buffering Strategies for Asymmetric Packet Switch Modules," *IEEE JSAC*, vol. 9, no. 3, pp. 428-438, April 1991.
24. T. Lin and L. Kleinrock, "Performance Analysis of Finite-Buffered Multistage Interconnection Networks with a General Traffic Pattern," *Manuscript*.
25. A. A. Nilsson, F. Lai and H. G. Perros, "An Approximate Analysis of a Bufferless $N \times N$ Synchronous Clos ATM Switch," *ITC-12*, 1990.
26. A. A. Nilsson, F. Lai and H. G. Perros, "Performance Evaluation of a Bufferless Synchronous Clos ATM Switch with Priorities and Space Preemption," *ICC'91*, pp. 379-384, 1991
27. J. Petersen, "Throughput Limitation by Head-of-Line Blocking," *ITC-13*, pp. 659-663, 1991.
28. T. H. Theimer, "Performance Comparison of Routing Strategies in ATM Switch Fabrics," *ITC-13*, pp. 923-928, 1991.
29. F. A. Tobagi, "Fast Packet Switch Architectures For Broadband Integrated Services Digital Networks," *Proc. IEEE*, vol. 78, no. 1, pp. 133-167, January 1990.
30. F. A. Tobagi and T. Kwok, "Fast Packet Switch Architectures and the Tandem Banyan Switch Fabric," *Manuscript*.
31. C. B. Woodworth, M. J. Karol and R. D. Gillin, "A Flexible Broadband Packet Switch for a Multimedia Integrated Network," *ICC '91*, pp. 78-85, 1991.

Traffic Source Characterization and Statistical Multiplexing

32. S. L. Albin, "Approximating a Point Process by a Renewal Process, II: Superposition Arrival Processes to Queues," *Op. Res.*, vol. 32, no. 5, pp. 1133-1162, September-October 1984.

33. J. Andrade, W. Burakowski and M. Villen-Altamirano, "Characterization of Cell traffic Generated by an ATM Source," *ITC-13*, pp. 545-550, 1991.
34. D. Anick, D. Mitra and M. M. Sondhi, "Stochastic Theory of a Data-Handling System with Multiple Sources," *BSTJ*, vol. 61, no. 8, pp. 1871-1894, October 1982.
35. T. Bell and K. Pawlikowski, "The Effect of Data Compression on Packet Sizes in Data Communication Systems," *ITC-13*, pp. 551-556, 1991.
36. C. Blondia, "The N/G/1 Finite Capacity Queue," *Stochastic Models*, vol. 5, no. 2, 1989.
37. U. Briem, T. H. Theimer and H. Kröner, "A General Discrete-Time Queueing Model: Analysis and Applications," *ITC-13*, pp. 13-19, 1991.
38. J. P. Cosmas and A. Odinma-Okafor, "Characterization of Variable Rate Video Codecs in ATM to a Geometrically Modulated Deterministic Process Model," *ITC-13*, pp. 773-780, 1991.
39. R. M. R.-Dagnino, M. R. K. Khansari and A. Leon-Garcia, "Prediction of Bit Rate Sequences of Encoded Video Signals," *IEEE JSAC*, vol. 9, no. 3, pp. 305-314, April 1991.
40. J. N. Daigle and J. D. Langford, "Queueing Analysis of a Packet Voice Communication System," *INFOCOM '85*, pp. 18-26, 1985.
41. J. N. Daigle and J. D. Langford, "Models for Analysis of Packet Voice Communications Systems," *IEEE JSAC*, vol. SAC-4, no. 6, pp. 847-855, September 1986.
42. W. Ding, "A Unified Correlated Input Process Model for Telecommunication Networks," *ITC-13*, pp. 539-544, 1991.
43. L. Dittmann and S. B. Jacobsen, "Statistical Multiplexing of Identical Bursty Sources in an ATM Network," *GLOBECOM '88*, pp. 1293-1297, 1988.
44. L. G. Dron, G. Ramamurthy and B. Sengupta, "Delay Analysis of Continuous Bit-Rate Traffic Over an ATM Network," *IEEE JSAC*, vol. 9, no. 3, pp. 402-407, April 1991.
45. A. E. Eckberg, "The Single Server Queue with Periodic Arrival Process and Deterministic Service Times," *IEEE Trans. Comm.*, vol. COM-27, no. 3, pp. 556-562, March 1979.
46. A. E. Eckberg, "Generalized Peakedness of Teletraffic Processes," *ITC-10*, 1983.
47. A. I. Elwalid, D. Mitra and T. E. Stern, "Statistical Multiplexing of Markov Modulated Sources: Theory and Computational Algorithms," *ITC-13*, pp. 495-500, 1991.
48. K. Fendick, V. Saksena and W. Whitt, "Dependence in Packet Queues: A Multi-Class Batch Poisson Model," *ITC-12*, pp. 1450-1454, 1989.
49. L. J. Forys and D. E. Smith, "Servicing Bursty Systems," *Comp. Networks and ISDN Sys.*, vol. 20, pp. 171-177, 1990.
50. M. Ghanbari, "Two-Layer Coding of Video Signals for VBR Networks," *IEEE JSAC*, vol. 7, no. 5, pp. 771-781, June 1989.
51. J. G. Gruber, "A Comparison of Measured and Calculated Speech Temporal Parameters Relevant to Speech Activity Detection," *IEEE Trans. Comm.*, vol. COM-30, no. 4, pp. 728-738, April 1982.
52. R. Grünenfelder, J. P. Cosmas, S. Manthorpe, A. Odinma-Okafor, "Characterization of Video Codecs as Autoregressive Moving Average Processes and Related Queueing System Performance," *IEEE JSAC*, vol. 9, no. 3, pp. 284-293, April 1991.
53. R. Grünenfelder, J. P. Cosmas, S. Manthorpe, A. Odinma-Okafor, "Measurement and ARMA Model of Video Codecs in an ATM Network," *ITC-13*, pp. 981-985, 1991.
54. R. Gusella, "Characterizing the Variability of Arrival Processes with Indexes of Dispersion," *IEEE JSAC*, vol. 9, no. 2, pp. 203-212, February 1991.
55. O. Hashida, Y. Takahashi and S. Shimogawa, "Switched Batch Bernoulli Process (SBBP) Queue with Application to Statistical Multiplexer Performance," *IEEE JSAC*, vol. 9, no. 3, pp. 394-401, April 1991.
56. O. Hashida and Y. Takahashi, "A Discrete-Time Priority Queue with Switched Batch Bernoulli Process Inputs and Constant Service Time," *ITC-13*, pp. 521-526, 1991.
57. H. Heffes, "A Class of Data Traffic Processes - Covariance Function Characterization and Related Queueing Results," *BSTJ*, vol. 59, no. 6, pp. 897-929, July-August 1980.
58. H. Heffes and D. Lucantoni, "A Markov Modulated Characterization of Packetized Voice and Data Traffic and Related Statistical Multiplexer Performance," *IEEE JSAC*, vol. SAC-4, no. 6, pp. 856-868, September 1986.

59. M. Hirano and N. Watanabe, "Characteristics of a Cell Multiplexer for Bursty ATM Traffic," *ICC '89*, pp. 399-403, 1989.
60. S. Huang, "Source Modelling for Packet Video," *ICC '88*, pp. 1262-1267, 1988.
61. S. Huang, "Modeling and Analysis for Packet Video," *GLOBECOM '89*, pp. 881-885, 1989.
62. I. Ide, "Superposition of Interrupted Poisson Processes and Its Application to Packetized Voice Multiplexers," *ITC-12*, pp. 3.1B.2.1-3.1B.2.7, 1988.
63. J. M. Karlsson, H. G. Perros and I. Viniotis, "Adaptive Polling Schemes for an ATM Bus," *ICC '91*, pp. 403-407, 1991.
64. K. Kawashima and H. Saito, "Teletraffic Issues in ATM Networks," *Comp. Networks and ISDN Sys.*, vol. 20, pp. 369-375, 1990.
65. B. G. Kim, "Characterization of Arrival Statistics of Multiplexed Voce Packets," *IEEE JSAC*, vol. SAC-1, no. 6, pp. 1133-1139, December 1983.
66. R. Kishimoto, Y. Ogata and F. Inumaru, "Generation Interval Distribution Characteristics of Packetized Variable Rate Video Coding Data Streams in an ATM Network," *IEEE JSAC*, vol. 7, no. 5, pp. 833-841, June 1989.
67. F. Kishino, K. Manabe, Y. Hayashi and H. Yasuda, "Variable Bit-Rate Coding of Video Signals for ATM Networks," *IEEE JSAC*, vol. 7, no. 5, pp. 801-806, June 1989.
68. H. Kröner, T. E. Theimer and U. Briem, "Queueing Models for ATM systems - A Comparison," *Manuscript*.
69. A. Kuczura, "The Interrupted Poisson Process as an Overflow Process," *BSTJ*, vol. 52, no. 3, pp. 437-448, March 1973.
70. A. A. Lazar, G. Pacifici and J. S. White, "Real-Time Traffic Measurements on MAGNET II," *ICC '90*, pp. 1191-1196, 1990.
71. D.-S. Lee, K.-H. Tzou and S.-Q. Li, "Control Analysis of video packet loss in ATM Networks," *SPIE Vol. 1360 Visual Communications and Image Processing '90*, pp. 1232-1243, 1990.
72. S.-Q. Li, "A General Solution Technique for Discrete Queueing Analysis of Multimedia Traffic on ATM," *IEEE Trans. Comm.*, vol. 39, no. 7, pp. 1115-1132, July 1991.
73. K. Q. Liao and L. G. Mason, "A Discrete-Time Single Server Queue With A Two Level Modulated Input and its Applications," *GLOBECOM '89*, pp. 913-918, 1989.
74. J. R. Louvion, J. Boyer and J. B. Gravereaux, "Statistical Multiplexing of VBR Sources in ATM Networks," *3rd IEEE CAMAD Workshop*, 1990.
75. H. Madsen and B. F. Nielsen, "The Use of Phase Type Distributions for Modeling Packet-Switched Traffic," *ITC-13*, pp. 593-599, 1991.
76. B. Maglaris, D. Anastassiou, P. Sen, G. Karlsson and J. D. Robbins, "Performance Models of Statistical Multiplexing in Packet Video Communications," *IEEE Trans. Comm.*, vol. 36, no. 7, pp. 834-844, July 1988.
77. M. Murata, Y. Ole, T. Suda and H. Miyahara, "Analysis of a Discrete-Time Single-Server Queue with Bursty Inputs for Traffic Control in ATM Networks," *GLOBECOM '89*, pp. 1781-1787, 1989.
78. R. Nagarajan, J. F. Kurose and D. Towsley, "Approximation Techniques for Computing Packet Loss in Finite-Buffered Voice Multiplexers," *IEEE JSAC*, vol. 9, no. 3, pp. 368-377, 1991.
79. M. F. Neuts, "A Versatile Markovian Point Process," *J. Appl. Prob.*, vol. 16, pp. 764-779, 1979.
80. M. F. Neuts, "Matrix Geometric Solutions in Stochastic Models," Baltimore MD, Johns Hopkins University Press, 1981.
81. M. Nomura, T. Fujii and N. Ohta, "Basic Characteristics of Variable Rate Video Coding in ATM Environment," *IEEE JSAC*, vol. 7, no. 5, pp. 752-760, June 1989.
82. K. Nørgaard, "Evaluation of output traffic from an ATM node," *ITC-13*, pp. 533-537, 1991.
83. I. Norros, J. W. Roberts, A. Simonian and J. T. Virtamo, "The Superposition of Variable Bit Rate Sources in an ATM Multiplexer," *IEEE JSAC*, vol. 9, no. 3, pp. 378-387, April 1991.
84. Y. Ohba, M. Murata and H. Miyahara, "Analysis of Interdeparture Processes for Bursty Traffic in ATM Networks," *IEEE JSAC*, vol. 9, no. 3, pp. 468-476, April 1991.

85. N. Ohta, M. Nomura and T. Fujii, "Variable Rate Video Coding Using Motion-Compensated DCT for Asynchronous Transfer Mode Networks," *ICC '88*, pp. 1257-1261, 1988
86. H. G. Perros and R. O. Onvural, "On the Superposition of Arrival Processes for Voice and Data," *Proc. 4th Int. Conf. Data Comm. Sys. and their Performance*, Barcelona, Spain, pp. 341-357, 1990.
87. G. Ramamurthy and B. Sengupta, "Delay Analysis of a Packet Voice Multiplexer by the $\Sigma D/D/1$ Queue," *IEEE Trans. Comm.*, vol. 39, no. 7, pp. 1107-1114, July 1991.
88. V. Ramaswami, "The N/G/1 Queue and its Detailed Analysis," *Adv. Appl. Prob.*, vol. 12, pp. 222-261, 1980.
89. V. Ramaswami, M. Rumsewicz, W. Willinger and T. Eliazov, "Comparison of some traffic models for ATM performance studies," *ITC-13*, pp. 7-12, 1991.
90. M. H. Rossiter, "The Switched Poisson Process and the SPP/G/1 Queue," *ITC-12*, pp. 3.1B.3.1-3.1B.3.7, 1988.
91. H. Saito, "The Departure Process of an N/G/1 Queue," *Performance Evaluation*, vol. 11, pp. 241-251, 1990.
92. H. Saito, M. Kawarasaki and H. Yamada, "An Analysis of Statistical Multiplexing in an ATM Transport Network," *IEEE JSAC*, vol. 9, no. 3, pp. 359-367, April 1991.
93. H. Saito, "Optimal control of variable Rate Coding with Incomplete Observation in Integrated Voice/Data Packet Networks," *European J. Op. Res.*, vol 51, pp. 47-64, 1991.
94. P. Sen, B. Maglaris, N. Rikli and D. Anastassiou, "Models for Packet Switching Of Variable-Bit-Rate Video Sources," *IEEE JSAC*, vol. 7, no. 5, pp. 865-869, June 1989. *INFOCOM '90*, pp. 124-131, 1990.
95. J. Solé, J. Domingo and J. Garcia, "Modelling the Bursty Characteristics of ATM Cell Streams," *Manuscript*.
96. K. Sriram and W. Whitt, "Characterizing Superposition Arrival Processes in Packet Multiplexers for Voice and Data," *IEEE JSAC*, vol. SAC-4, no. 6, pp. 833-846, September 1986.
97. K. Sriram, R. S. McKinney and M. H. Sherif, "Voice Packetization and Compression in Broadband ATM Networks," *IEEE JSAC*, vol. 9, no. 3, pp. 294-304, April 1991.
98. T. E. Stern, "A Queueing Analysis of Packet Voice," *GLOBECOM '83*, pp. 71-76, 1983.
99. W. Verbiest, L. Pinnoo and B. Voeten, "The Impact of ATM Concept on Video Coding," *IEEE JSAC*, vol. 6, no. 9, pp. 1623-1632, December 1988.
100. W. Verbiest and L. Pinnoo, "A Variable Rate Video Codec for Asynchronous Transfer Mode Networks," *IEEE JSAC*, vol. 7, no. 5, pp. 761-770, June 1989.
101. W. Whitt, "Approximating a Point Process by a Renewal Process, I: Two Basic Methods," *Op. Res.*, vol. 30, no. 1, pp. 125-147, January-February 1982.
102. W. Whitt, "The Queueing Network Analyzer," *BSTJ*, vol. 62, no. 9, pp. 2779-2815, November 1983.
103. W. Whitt, "Performance of the Queueing Network Analyzer," *BSTJ*, vol. 62, no. 9, pp. 2817-2843, November 1983.
104. H. Yamada and S. Sumita, "A Traffic Measurement Method and its Application for Cell Loss Probability Estimation in ATM Networks," *IEEE JSAC*, vol. 9, no. 3, pp. 315-324, April 1991.
105. H. Yamashita, H. G. Perros and S. W. Hong, "Performance Modeling of a Shared Buffer ATM Switch Architecture," *ITC-13*, pp. 993-998, 1991.
106. Y. Yasuda, H. Yasuda, N. Ohta and F. Kishino, "Packet Video Transmission through ATM Networks," *GLOBECOM '89*, pp. 876-880, 1989.
107. Y. Yatsuzuka, "Highly Sensitive Speech Detector and High Speed Voiceband Data Discriminator in DSI-ADPCM Systems," *IEEE Trans. Comm.*, vol. COM-30, no. 4, pp. 738-750, April 1982.
108. C. Ziegler and D. L. Schilling, "Waiting Times at Very Fast, Constant Service Time Merger Nodes," *IEEE Trans. Comm.*, vol. COM-32, no. 2, pp. 189-194, February 1984.

Call Admission

109. A. Baiocchi et al., "Loss Performance Analysis of an ATM Multiplexer Loaded with High-Speed ON-OFF Sources," *IEEE JSAC*, vol. 9, no. 3, pp. 388-393, April 1991.
110. A. W. Berger, "Determination of Load-Service Curves for Distributed Switching Systems: Probabilistic Analysis of Overload-Control Schemes," *ITC-13*, pp. 435-440, 1991.
111. P. Castelli, E. Cavallero and A. Tonietti, "Policing And Call Admission Problems in ATM Networks," *ITC-13*, pp. 847-852, 1991.
112. B. Doshi and H. Heffes, "Overload Performance of an Adaptive, Buffer-Window Allocation Scheme for a Class of High Speed Networks," *ITC-13*, pp. 441-446, 1991.
113. Z. Dziong, K.-Q. Liao, and L. Mason, "Flow Control Models for Multi-Service Networks with Delayed Call Set Up," *INFOCOM '90*, pp. 39-46, 1990.
114. Z. Dziong, K.-Q. Liao, L. Mason and N. Tetrault, "Bandwidth Management in ATM Networks," *ITC-13*, pp. 821-827, 1991.
115. J. Filipiak, "Structured Systems Analysis Methodology for Design of an ATM Network Architecture," *IEEE JSAC*, vol. 7, no. 8, pp. 1263-1273, October 1989.
116. G. Gallassi, G. Rigolio and L. Fratta, "ATM: Bandwidth Assignment and Bandwidth Enforcement Policies," *GLOBECOM '89*, pp. 1788-1793, 1989.
117. M. Gerla, J. A. S. Monteiro and R. Pazos, "Topology Design and Bandwidth Allocation in ATM Nets," *IEEE JSAC*, vol. 7, no. 8, pp. 1253-1262, October 1989.
118. R. Guerin, H. Ahmadi and M. Naghshineh, "Equivalent Capacity and Its Application to Bandwidth Allocation in High-Speed Networks," *7th ITC Seminar*, Morristown, NJ, October 9-11, 1990.
119. J. Y. Hui, "Resource Allocation for Broadband Networks," *IEEE JSAC*, vol. 6, no. 9, pp. 1598-1608, December 1989.
120. P. Joos and W. Verbiest, "A Statistical Bandwidth Allocation and Usage Monitoring Algorithm for ATM Networks," *ICC '89*, pp. 415-422, 1989.
121. T. Kamitake and T. Suda, "Evaluation of an Admission Control Scheme for an ATM Network Considering Fluctuations in Cell Loss Rate," *GLOBECOM '89*, pp. 1774-1780, 1989.
122. S.-Y. R. Li, "Algorithms for Flow Control and Call Set-Up in Multi-Hop Broadband ISDN," *INFOCOM '90*, pp. 889-895, 1990.
123. Y. Miyao, "A Call Admission Control Scheme in ATM Networks," *ICC '91*, pp. 391-396, 1991.
124. T. Murase, H. Suzuki and T. Takeuchi, "A Call Admission Control for ATM Networks Based on Individual Multiplexed Traffic Characteristics," *ICC '91*, pp. 193-198, 1991.
125. M. Ohta, "Fluid Model for a Traffic Congestion Prediction," *ITC-13*, pp. 665-670, 1991.
126. C. Rasmussen, J. H. Sørensen, K. S. Kvols and S. B. Jacobsen, "Source-Independent Call Acceptance Procedures in ATM Networks," *IEEE JSAC*, vol. 9, no. 3, pp. 351-358, April 1991.
127. G. Rigolio and L. Fratta, "Input Rate Regulation and Bandwidth Assignment in ATM Networks: an Integrated Approach," *ITC-13*, pp. 141-146, 1991.
128. L. B.-Saez and G. H. Petit, "Bandwidth Resource Dimensioning in ATM Networks: A Theoretical Approach and Some Study Cases," *ITC-13*, pp. 929-934, 1991.
129. K. Sriram and D. M. Lucantoni, "Traffic Smoothing Effects of Bit Dropping in a Packet Voice Multiplexer," *INFOCOM '88*, pp. 759-770, 1988.
130. E. D. Sykas, K. M. Vlakos, I. S. Venieris and E. N. Protonotarios, "Simulative Analysis of Optimal Resource Allocation and Routing in IBCN's," *IEEE JSAC*, vol. 9, no. 3, pp. 486-492, April 1991.
131. J. T. Virtamo and J. W. Roberts, "Evaluating Buffer Requirements in an ATM Multiplexer," *GLOBECOM '89*, pp. 1473-1477, 1989.
132. Q. Wang and V.S. Frost, "Efficient Estimation of Cell Blocking Probability for ATM Systems," *ICC '91*, pp. 385-390, 1991.
133. A. K. Wong, "On Buffer Dimensioning and Static Rate-Control in Broadband ATM Networks," *ICC '91*, pp. 280-286, 1991.

Congestion Control and Source Policing

134. H. Ahmadi, R. Guerin and K. Sohraby, "Analysis of Leaky Bucket Access Control Mechanism with Batch Arrival Process," *Draft*, for Globecom 1990.
135. K. Bala, I. Cidon and K. Sohraby, "Congestion Control for High Speed Packet Switched Networks," *INFOCOM '90*, pp. 520-526, 1990.
136. A. W. Berger, "Overload Control Using Rate Control Throttle: Selecting Token Bank Capacity for Robustness to Arrival Rates," *IEEE Trans. Autom. Control*, vol. 36, no. 2, pp. 216-219, February 1991.
137. F. Borgonovo and L. Fratta, "Policing Procedures: Implications, Definitions and Proposals," *ITC-13*, pp. 859-866, 1991.
138. P. F. Boyer, "Congestion Control for the ATM," *7th Int. Teletraffic Congress Seminar*, Morristown NJ, October 9-11, 1990.
139. M. Butto, E. Cavallero and A. Tonietti, "Effectiveness of the 'Leaky Bucket' Policing Mechanism in ATM Networks," *IEEE JSAC*, vol. 9, no. 3, pp. 335-342, April 1991.
140. H. J. Chao, "Design of Leaky Bucket Access Control Schemes in ATM Networks," *ICC '91*, pp. 180-187, 1991.
141. M. Chen, "A Services Features Oriented Congestion Control Scheme for a Broadband Network," *ICC '91*, pp. 105-109, 1991.
142. L. Dittmann, S. B. Jacobsen and K. Moth, "Flow Enforcement Algorithms for ATM Networks," *IEEE JSAC*, vol. 9, no. 3, pp. 343-350, April 1991.
143. A. E. Eckberg, D. T. Luan and D. M. Lucantoni, "Bandwidth Management: A Congestion Control Strategy for Broadband Packet Networks - characterizing the throughput burstiness Filter," *Manuscript*.
144. A. E. Eckberg, D. T. Luan and D. M. Lucantoni, "Meeting the Challenge: Congestion and Flow Control Strategies for Broadband Information Transport," *GLOBECOM '89*, pp. 1769-1773, 1989.
145. A. Gersht and K. J. Lee, "A Congestion Control Framework For ATM Networks," *INFOCOM '89*, pp. 701-710, 1989.
146. S. J. Golestani, "Congestion-Free Transmission of Real-Time Traffic in Packet Networks," *INFOCOM '90*, pp. 527-536, 1990.
147. Z. Haas and J. H. Winters, "Congestion Control by Adaptive Admission," *INFOCOM '91*, pp. 560-569, 1991.
148. A. Hac, "Congestion Control and Switch Buffer Allocation in High-Speed Networks," *INFOCOM '91*, pp. 314-322, 1991.
149. D. P. Heyman, "A Performance Model of the Credit Manager Algorithm," *Manuscript*.
150. M. Hirano and N. Watanabe, "Traffic Characterization and a Congestion Control Scheme for an ATM Network," *Int. J. Digital and Analog Comm. Sys.*, vol. 3, pp. 211-217, 1990.
151. D. Hong, T. Suda and J. J. Bae, "Survey of Techniques for Prevention and Control of Congestion in an ATM Network," *ICC '91*, pp. 204-210, 1991.
152. D. A. Hughes, H. S. Bradlow and G. Anido, "Congestion Control in an ATM Network," *ITC-13*, pp. 835-840, 1991.
153. A. Jalali and L. G. Mason, "Open Loop Schemes for Network Congestion Control," *ICC '91*, pp. 199-203, 1991.
154. W. E. Leland, "Window-Based Congestion Management in Broadband ATM Networks: The Performance of Three Access-Control Policies," *GLOBECOM '89*, pp. 1794-1800, 1989.
155. O. A. Magd, H. Gilbert and M. Wernik, "Flow and Congestion Control for Broadband Packet Networks," *ITC-13*, pp. 853-858, 1991.
156. D. Mitra, "Optimal Design of Windows for High Speed Data Networks," *INFOCOM '90*, pp. 1156-1163, 1990.
157. G. Ramamurthy and R. S. Dighe, "A Multidimensional Framework for Congestion Control in B-ISDN," *IEEE JSAC*, 9-9, pp. 1440-1451, 1991.

158. G. Ramamurthy and R. S. Dighe, "Distributed Source Control: A Network Access Control for Integrated Broadband Packet Networks," *INFOCOM '90*, pp. 896-907, 1990.
159. E. P. Rathgeb, "Modeling and Performance Comparison of Policing Mechanisms for ATM Networks," *IEEE JSAC*, vol. 9, no. 3, pp. 325-334, April 1991.
160. T. Sabourin, G. Fiche and M. Ligeour, "Overload Control in a Distributed System," *ITC-13*, pp. 421-427, 1991.
161. H. Schulzrinne, J. F. Kurose and D. Towsley, "Congestion Control for Real-Time Traffic in High-Speed Networks," *INFOCOM '90*, pp. 543-550, 1990.
162. M. Sidi, W.-Z. Liu, I. Cidon and I. Gopal, "Congestion Control Through Input Rate Regulation," *GLOBECOM '89*, pp. 49.2.1-49.2.5, 1989.
163. E. Unteregelsbacher and H. T. Mouftah, "PDF Based Congestion Control in ATM Networks," *ICC '91*, pp. 211-215, 1991.

Transport Protocols

164. H. Ahmadi and P. Kermani, "Throughput Analysis of a Class of Selective Repeat Protocols in High-Speed Environments," *GLOBECOM '89*, pp. 930-938, 1989.
165. A. E. Baratz, J. P. Gray, P. E. Green, J. M. Jaffe and D. P. Pozefsky, "SNA Networks of Small Systems," *IEEE JSAC*, vol. SAC-3, no. 3, pp. 416-426, May 1985.
166. E. W. Biersack and D.C. Feldmeier, "Transport Protocol Issues for ATM Based Networks", *Proc. 8th European Fibre Optic Comm. and LAN Exposition*, West Germany, 1990
167. D. R. Cheriton, C. L. Williamson, "VMTP as the Transport Layer for High-Performance Distributed Systems," *IEEE Comm. Mag.*, pp. 37-44, June 1989.
168. D. Clark, M. L. Lambert and L. Zhang, "NETBLT: A Bulk Data Transfer Protocol," *RFC 998*, March 1987.
169. D. D. Clark, V. Jacobson, J. Romkey and H. Salwen, "An Analysis of TCP Processing Overhead," *IEEE Comm. Mag.*, pp. 23-29, June 1989.
170. D. E. Comer, "Internetworking with TCP/IP: Principles, Protocols and Architecture," *Prentice-Hall*, 1988.
171. W. A. Doeringer, D. Dykeman, M. Kaiserwerth, B. W. Meister, H. Rudin and R. Williamson, "A Survey of Light-Weight Transport Protocols for High-Speed Networks," *IEEE Trans. Comm.*, vol. 38, no. 11, pp. 2025-2039, November 1990.
172. D. Dykeman and M. Kaiserwerth, "Tutorial: High-Speed Protocols," *3rd IFIP Conference on High-Speed Networking*, March 19, 1991.
173. G. M. Garner, "End-to-End Performance Modeling for Virtual Circuit Networks," *ITC-13*, pp. 371-376, 1991.
174. M. Gerla and L. Kleinrock, "Flow Control: A Comparative Survey," *IEEE Trans. Comm.*, vol. COM-28, no. 4, pp. 289-310, April 1980.
175. O. Gihir and P. J. Kuehn, "Comparison of Communication Services with Connection-Oriented and Connectionless Data Transmission," *Proc. Int. Seminar on Computer Networking and Performance Evaluation*, Tokyo, Japan, September 1985.
176. P. E. Green, R. J. Chappuis, J. D. Fisher, P. S. Frosch and C. E. Wood, "A Perspective on Advanced Peer-To-Peer Networking," *IBM Sys. Journal*, vol. 26, no. 4, pp. 414-427, 1987.
177. S. Heatley and D. Stockesberry, "Analysis of Transport Measurements Over a Local Area Network," *IEEE Comm. Mag.*, pp. 16-22, June 1989.
178. V. Jacobson, "Congestion Avoidance and Control," *SIGCOMM '88*, pp. 314-329, 1988.
179. R. Jain, "A Timeout-Based Congestion Control Scheme for Window Flow-Controlled Networks," *IEEE JSAC*, vol. SAC-4, no. 7, pp. 1162-1167, October 1986.
180. id=p281.T. F. La Porta and M. Schwartz, "Architectures, Features, and Implementation of High Speed Transport Protocols", *Proc. GLOBECOM'91*, 1991
181. W. S. Lai, "Protocols for High-Speed Networks," *INFOCOM '90*, pp. 1268-1269, 1990.
182. C. Partridge, "Workshop report; Internet Research Steering Group Workshop on Very-High-Speed Networks," *RFC 1152*, April 1990.
183. A. R. Pach, "A Technique for Calculation of the optimal timeout for the class 4 Transport Protocol in a Packet Switched Network," *ITC-13*, pp. 291-296, 1991.

184. K. Sabnani and A. Netravali, "A High Speed Transport Protocol for Datagram/Virtual Circuit Networks," *SIGCOMM '89*, pp. 146-157, 1989.
185. R. M. Sanders, "The Xpress Transfer Protocol (XTP) A Tutorial," *Univ. of Virginia Comp. Sci. Dept.*, TR-89-10, November 1, 1990.
186. R. A. Sultan, P. Kermani, G. A. Grover, T. P. Barzilai and A. E. Baratz, "Implementing System/36 Advanced Peer-To-Peer Networking," *IBM Sys. Journal*, vol. 26, no. 4, pp. 429-451, 1987.
187. R. W. Watson, "Delta-T Protocol Specification," *Lawrence Livermore Lab.*, Report UCID-19293, April 15, 1983.

Routing

188. J. J. G.-L.-Aceveres, "A New Minimum-Hop Routing Algorithm," *INFOCOM '87*, pp. 170-180, 1987.
189. J. M. Akinpelu, "The Overload Performance of Engineered Networks with Nonhierarchical and Hierarchical Routing," *BSTJ*, vol. 63, no. 7, pp. 1261-1281, September 1984.
190. G. R. Ash, A. H. Kafker and K. R. Krishnan, "Servicing and Real-Time Control of Networks with Dynamic Routing," *BSTJ*, vol. 60, no. 8, pp. 1821-1845, October 1981.
191. G. R. Ash, R. H. Cardwell and R. P. Murray, "Design and Optimization of Networks with Dynamic Routing," *BSTJ*, vol. 60, no. 8, pp. 1787-1820, October 1981.
192. G. R. Ash and E. Oberer, "Dynamic Routing in the AT&T Network - Improved Service Quality at Lower Cost," *GLOBECOM '89*, pp. 303-308, 1989.
193. G. R. Ash, J.-S. Chen, A. E. Frey and B. D. Huang, "Real Time Network Routing in a Dynamic Class-Of-Service Network," *ITC-13*, pp. 187-194, 1991.
194. C. G. Cassandras, M. H. Kallmes and D. Towsley, "Optimal Routing and Flow Control in Networks with Real Time Traffic," *INFOCOM '89*, pp. 784-791, 1989.
195. P. Chemouil, M. Lebourges and P. Gauthier, "Performance Evaluation of Adaptive Traffic Routing in a Metropolitan Network: A Case Study," *GLOBECOM '89*, pp. 314-318, 1989.
196. I. Cidon and I. S. Gopal, "Dynamic Tree Detection in Computer Networks," *INFOCOM '87*, pp. 181-187, 1987.
197. A. Di Benedetto, P. La Nave and C. Sisto, "Dynamic Routing of the Italcable Telephone Traffic: Experiences and Perspectives," *GLOBECOM '89*, pp. 309-313, 1989.
198. A. E. Economides, P. A. Ioannou and J. A. Silvester, "Decentralized Adaptive Routing for Virtual Circuit Networks Using Stochastic Learning Automata," *INFOCOM '88*, pp. 613-622, 1988.
199. E. Granel et al., "A Comparative Study of Several Dynamic Routing Algorithms with Adaptive Preselection and Selection Phases," *ITC-13*, pp. 383-388, 1991.
200. P. A. Humblet, "Another Adaptive Distributed Shortest Path Algorithm," *IEEE Trans. Comm.*, vol. 39, no. 6, pp. 995-1003, June 1991.
201. R. R. Jueneman and G. S. Kerr, "Explicit Path Routing in Communications Networks," *Proc. Int. Conference on Computer Communication*, pp. 340-342, 1976.
202. K. Kamimura and H. Nishino, "Capacity and flow assignment of packet-switched networks with concave line cost function," *ITC-13*, pp. 285-290, 1991.
203. Y. Kanayama, Y. Maeda, and H. Ueda, "Virtual Path Management Functions for Broadband ATM Networks," *Proc GLOBECOM'91*, 1991.
204. K. R. Krishnan, "Adaptive State-Dependent Traffic Routing Using On-Line Trunk-Group Measurements," *ITC-13*, pp. 407-411, 1991.
205. K. J. Lee, D. Towsley and M. Choi, "Distributed Algorithms with Constraints in Communication Networks," *INFOCOM '87*, pp. 188-199, 1987.
206. K. J. Lee and B. Kadaba, "Distributed Routing Using Topology Database in Large Computer Networks," *INFOCOM '88*, pp. 593-602, 1988.
207. G. Ludwig and R. Roy, "Saturation Routing Network Limits," *Proc. IEEE*, pp. 1353-1362, 1977.
208. B. Maglaris, R. Boorstyn, S. Panwar and T. Spirtos, "Routing in Bursty-Switched Voice/Data Integrated Networks," *INFOCOM '87*, pp. 162-169, 1987.

209. B. Maglaris et al., "Routing of Voice and Data in Burst-Switched Networks," *IEEE Trans. Comm.*, vol. 38, no. 6, pp. 889-897, June 1990.
210. D. Mitra, R. J. Gibbens and B. D. Huang, "Analysis and Optimal Design of Aggregated LEast Busy Alternative Routing on Symmetric Loss Networks With Trunk Reservations," *ITC-13*, pp. 477-482, 1991.
211. Y. Sato and K. Sato, "Virtual Path and Link Capacity Design for ATM Networks," *IEEE JSAC*, vol. 9, no. 1, pp. 104-111, January 1991.
212. Y. Sato, et. al., "Experimental ATM Transport System and Virtual Path Management Techniques", *Proc. GLOBECOM'91*, 1991
213. M. Schwartz and T. E. Stern, "Routing Techniques Used in Computer Communication Networks," *IEEE Trans. Comm.*, vol. COM-28, no. 4, pp. 265-278, April 1980.
214. P. Semal, "Performance Evaluation of the Saturation Routing Method," *ITC-13*, pp. 389-394, 1991.
215. E. D. Sykas, K. V. Vlakos and E. N. Protonotarios, "Mathematical Tools for Analysis of ATM Systems," *ITC-13*, pp. 781-786, 1991.
216. S. Van Hoesel, P. Kellenberg and W. Schooten, "Routing and Multiplex Bundling in a Transmission Network," *ITC-13*, pp. 401-406, 1991.
217. Z. Zhang and H. L. Hartmann, "Optimal Routing in Virtual Circuit Communication Networks," *ITC-13*, pp. 395-400, 1991.

Fairness

218. G. A. Awater and F. C. Schoute, "Optimal Queueing Policies for Fast Packet Switching of Mixed Traffic," *IEEE JSAC*, vol. 9, no. 3, pp. 458-467, April 1991.
219. P. P. Bhattacharya and A. Ephremides, "Optimal Scheduling with Strict Deadlines," *Manuscript*.
220. T. M. Chen, J. Walrand and D. G. Messerschmitt, "Dynamic Priority Protocols for Packet Voice," *IEEE JSAC*, vol. 7, no. 5, pp. 632-643, June 1989.
221. R. Chipalkatti, J. F. Kurose and D. Towsley, "Scheduling Policies for Real-Time and Non-Real-Time Traffic in a Statistical Multiplexer", *INFOCOM '89*, pp. 774-783, 1989.
222. B. Doshi, S. Dravida, P. Johri and G. Ramamurthy, "Memory, Bandwidth, Processing and Fairness Considerations in Real Time Congestion Controls for Broadband Networks," *ITC-13*, pp. 153-159, 1991.
223. J. Garcia and O. Casals, "Priorities in ATM Networks," *Manuscript*.
224. A. Gravey and G. Hebuterne, "Mixing Time and Loss Priorities in a single Server Queue," *ITC-13*, pp. 147-152, 1991.
225. E. L. Hahne, C. R. Kalmanek and S.P. Morgan, "Fairness and Congestion Control on a Large ATM Data Network with Dynamically Adjustable Windows," *ITC-13*, pp. 867-872, 1991.
226. B. G. Haskell, "Buffer and Channel Sharing by Several Interframe Picturephone Coders," *BSTJ*, vol. 51, no. 1, pp. 261-289, January 1972.
227. H. Kröner, "Comparative Performance Study of Space Priority Mechanisms for ATM Networks, *Proc. IEEE Infocom*, 1990
228. H. Kröner, P. J. Kühn and G. Willmann, "Performance Comparison of Resource Sharing Strategies between Lost-Call-Cleared and Reservation Traffic," *ITC-13*, pp. 639-645, 1991.
229. J. Le Boudec, "An Efficient Solution Method for Markov Models of ATM Links with Loss Priorities," *IEEE JSAC*, vol. 9, no. 3, pp. 408-417, April 1991.
230. Y. Lim and J. Kobza, "Analysis of a Delay Dependent Priority Discipline in a Multi-Class Traffic Packet Switching Node," *INFOCOM '88*, pp. 889-898, 1988.
231. D. M. Lucantoni and S. P. Parekh, Selective Cell Discard Mechanisms for a B-ISDN Congestion Control Architecture, presented in *Proc. ITC-7 Seminar*, New Jersey, 1990
232. D. W. Petr and V.S. Frost, "Optimal Threshold Based Discarding for Queue Overload Control", presented in *Proc. ITC-7 Seminar*, New Jersey, 1990
233. H. Saito, "Optimal Queueing Discipline for Real-Time Traffic at ATM Switching Nodes," *IEEE Trans. Comm.*, vol. 38, no. 12, pp. 2131-2136, December 1990.

234. J. Schormans, J. Pitts and E. Scharf, "Time Priorities in ATM Switches," *ITC-13*, pp. 527-532, 1991.
235. K. Sriram, P. K. Varshney and J. G. Shantikumar, "Discrete-Time Analysis of Integrated Voice/Data Multiplexers With and Without Speech Activity Detectors," *IEEE JSAC*, vol. SAC-1, no. 6, pp. 1124-1132, December 1983.
236. K. H. Tseng and M. T. Hsiao, "Admission Control of Voice/Data Integration in an ATM Network," *ICC '91*, pp. 188-192, 1991.
237. R. C. F. Tucker, "Accurate Method for Analysis of a Packet Speech Multiplexer with Limited Delay," *IEEE Trans. Comm.*, vol. 36, no. 4, pp. 479-483, April 1988.

Error Control

238. J. J. Bae, T. Suda, and N. Watanabe, "Evaluation of Protocol Processing Overhead in Error Recovery Schemes for a High Speed Packet Switched Network: Link by Link versus Edge to Edge Schemes", *JSAC*, 9-9, pp. 1496-1509, 1991
239. A. Bhargava, J. F. Kurose, D. Towsley and G. Vanleemput, "Performance Comparison of Error Control Schemes in High-Speed Computer Communication Networks," *IEEE JSAC*, vol. 6, no. 9, pp. 1565-1575, December 1988.
240. A. B. Bondi, "On the Bunching of Cell Losses in ATM Based Networks", *Proc. GLOBECOM'91*, 1991
241. R. Burda and T. Uhl, "Performance Analysis of Entry-To-Exit Flow Control in a Virtual Channel," *ITC-13*, pp. 359-363, 1991.
242. B. T. Doshi, P. K. Johri, A. N. Netravali and K. K. Sabnani, "Retransmission Protocols and Flow Controls in High Speed Packet Networks," *ITC-13*, pp. 309-314, 1991.
243. B. Doshi, A. Eckberg, V. Saksena, and R. Zoccolillo, "An Overall B-ISDN/ATM Congestion/Flow/Error Control Architecture and Its Predicted Performance", *Proc. ITC-7 Seminar*, New Jersey, 1990
244. A. E. Eckberg, D. T. Luan and D. M. Lucantoni, "An Approach to Controlling Congestion in ATM Networks," *Manuscript*.
245. S. Fuhrmann and J. Le Boudec, "Burst and Cell Level Models for ATM Buffers," *ITC-13*, pp. 975-980, 1991.
246. C. Huitema and W. Dabbous, "End-to-End Transmission Control on ATM Networks," *Manuscript*.
247. H. Inai, T. Nishida, T. Yokohira and H. Miyahara, "End-to-End Performance Modeling for Layered Communication Protocol," *INFOCOM '90*, pp. 442-449, 1990.
248. Y. B.-Kim, A. G. Vacroux, "A Unified End-to-End Control Scheme for Fast Packet Networks at ISO/OSI TSAP," *ICC '91*, pp. 397-402, 1991.
249. T. Kitami and I. Tokizawa, "Cell Loss Compensation Schemes Employing Error Correction Coding for Asynchronous Broadband ISDN," *INFOCOM '90*, pp. 116-123, 1990.
250. S. Q. Li, "Study of Information Loss in Packet Voice Systems," *IEEE Trans. Comm.*, vol. 37, no. 11, pp. 1192-1202, November 1989.
251. K. Mase and S. Shioda, "Real-Time Network Management for ATM Networks," *ITC-13*, pp. 133-140, 1991.
252. I. Norros and J. T. Virtamo, "Who loses cells in the Case of Burst Scale Congestion," *ITC-13*, pp. 829-833, 1991.
253. N. Shacham, "Queueing Analysis of Selective-Repeat ARQ Receiver," *INFOCOM '87*, pp. 512-520, 1987.
254. N. Shacham and P. McKenney, "Packet Recovery in High-Speed Networks Using Coding and Buffer Management,"