On the performance analysis of ABR in ATM LANs with Stochastic Petri Nets

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Abstract

In this paper we use Generalized Stochastic Petri Nets (GSPNs) and Stochastic Well-formed Nets (SWNs) for the performance analysis of Asynchronous Transfer Mode (ATM) Local Area Networks (LANs) that adopt the Available Bit Rate (ABR) service category in its Relative Rate Marking (RRM) version. We also consider a peculiar version of RRM ABR called Stop & Go ABR; this is a simplified ABR algorithm designed for the provision of best-effort services in low-cost ATM LANs, according to which sources can transmit only at two different cell rates, the Peak Cell Rate (PCR) and Minimum Cell Rate (MCR). Results obtained from the solution of GSPN models of simple ATM LAN setups comprising RRM or Stop & Go ABR users, as well as Unspecified Bit Rate (UBR) users, are first validated through detailed simulations, and then used to show that Stop & Go ABR is capable of providing good performance and fairness in a number of different LAN configurations. We also develop SWN models of homogeneous ABR LANs, that efficiently and automatically exploit system symmetries allowing the investigation of larger LAN configurations.
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1. Introduction

The UBR and ABR service categories (or transfer capabilities) standardized by the ATM Forum and the ITU-T [1,2] are considered the two main approaches for the provision of best-effort services in ATM networks. UBR stands for Unspecified Bit Rate; UBR provides very simple means for the transfer of the data resulting from best-effort services through ATM networks. The problem of UBR is that it can be quite inefficient, depending on the network configuration and load. ABR stands for Available Bit Rate; ABR provides flow control algorithms with variable degree of sophistication and efficiency to exploit the bandwidth not used by guaranteed-quality services for the transfer of the data resulting from best-effort

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services. The problem of ABR is that the flow control algorithms that permit good performance to be obtained are rather complex.

Flow control in ABR is based on *Resource Management* (RM) cells that are periodically inserted within the flow of data cells along the connection; these RM cells travel from source to destination (forward RM cells), and then return to the source (backward RM cells). The ATM switches along the connection can use RM cells to notify sources about their congestion, and control the rate at which ABR sources inject cells into the network through feedback information. ABR sources are required to react to the feedback information by adequately modifying their cell transmission rates. Three ABR operating modes are specified; they define only the source behavior and the way the feedback is conveyed to sources, while the algorithm used in nodes to compute the feedback is not defined by standards. With Explicit Forward Congestion Indication (EFCI) ABR, just one bit of RM cells is used to convey to ABR sources the information about the congestion of the switches traversed by the connection (one bit in the header of data cells in the forward direction is also used with this operating mode). When sources receive RM cells with this bit set, they are required to reduce their cell transmission rate. With Relative Rate Marking (RRM) ABR, two bits of RM cells are used to instruct sources to reduce, to keep, or to increase their cell transmission rate. With Explicit Rate (ER) ABR, the congested switch along the connection path exactly instructs sources about the cell rate at which they are allowed to transmit (see for example [3,4]).

In a recent paper [5] a simplified implementation of RRM ABR was proposed and named Stop & Go ABR, in which sources can transmit only at two different cell rates, the Peak Cell Rate (PCR) and Minimum Cell Rate (MCR). Detailed simulation results of simple Local Area Network (LAN) configurations were used to show that Stop & Go ABR is capable of providing performance and fairness practically identical to those of traditional RRM ABR algorithms, while allowing a simpler implementation within ATM switches, thus possibly leading to reduced cost of the ATM LAN equipment.

Preliminary studies of the performance of ABR LANs with Generalized Stochastic Petri Net (GSPN) [6,7] models were presented in [8], considering the case of one ABR source.

In this paper we further expand the performance analysis of ATM LANs with both RRM and Stop & Go ABR users in two ways: first we develop GSPN models of ATM LANs comprising ABR as well as UBR users, validating the results obtained from the solution of GSPN and SWN models through detailed simulations, and showing that Stop & Go ABR is capable of providing good performance and fairness in the considered LAN configurations. Second, we exploit system symmetries in case of homogeneous ABR sources by developing Stochastic Well-formed Nets (SWNs) [12,14] models to reduce the model state space and analyze larger systems.

2. The GSPN approach to ATM network modeling

It was recently shown in the literature [8–10] that it is possible to analyze ATM networks using PN models in which all transitions are immediate, with just one exception: one transition is timed with a constant delay τ defining the time unit in the model. Note that this timed transition actually defines the clock of the model and thus always has concession. The stochastic process generated by the dynamic behavior of such a PN model is a semi-Markov process (SMP) with constant sojourn times, with an embedded discrete-time Markov chain (DTMC) whose evolution over the state space is isomorphic to the tangible marking process and whose transition probabilities are computed from the reachable markings and from the weights of the enabled immediate transitions.

However, the association of the only timed PN transition with either a constant or an exponentially distributed random delay makes no difference for the computation of a large quantity of interesting steady-state performance parameters. Indeed, while the PN model with the deterministic transition originates a DTMC, the PN model with the exponential transition originates a continuous-time Markov chain (CTMC); the relation between the two MCs is very tight: the DTMC is the em-