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Performance Analysis of the ATM Adaptation Layer 2 (AAL2)

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Abstract: In this paper, we analyze the performance of AAL2 multiplexer for a continuous time Markovian arrival process. AAL2 CPS (Common Part Sublayer) packets are multiplexed in the AAL2 multiplexing queue and transmitted in the transmission queue. This tandem structure suggests that the statistics of AAL2 CPS requires at least 2 dimensional state space. Furthermore, from a network-level point of view, cell multiplexing and de-multiplexing procedures are repeated at each AAL2 switching node. That requires simple analysis model. To solve this problem, we reduce the state space by showing that the output process of multiplexing queue can be modeled with the Coxian distribution. We propose a single dimension analysis model of the CPS transmission queue. When AAL2 convey both real and non real time short packets, QoS management is a problem. This is because the QoS of real time as well as non-real time packets is measured using different metrics – delay and cell loss ratio respectively. Most previous work is concentrated around delay performance due to the real time applications getting the primary attention. From the direct comparison of delay and CLR performance, we show that delay constraint is the dominant parameter in QoS of AAL2.

Keywords: ATM adaptation layer, AAL2, Performance Evaluation, Cell loss ratio

1. Introduction

The third generation (3G) mobile communication systems support multimedia services. Such applications require a broad range of transmission rates and various kinds of QoS, such as provided by ATM networks. Since ATM is the base station interconnection technology, an important issue is how to flexibly support various types of information using ATM networks. To utilize the bandwidth of ATM networks near fully and flexibly, we need a proper ATM adaptation layer (AAL). AAL1, AAL3/4, and AAL5 do not provide both high bandwidth efficiency and low delay characteristics. AAL2 was developed to be standardized at the ITU-T [1] for this purpose.

There have been a number of studies on the issues related to performance [2–4] and design of the AAL2 for Universal Terrestrial Radio Access Network (UTRAN) in UMTS/IMT-2000 [5–10]. The basic structure of AAL2 transmitter is depicted in Fig. 1. In order to analyze the AAL2 transmitter, which is composed of the multiplexing queue and transmission queue, there are two approaches. The first method is to directly analyze the entire AAL2 transmitter. In this case, a quite complex calculation is generally required. For example, in [2–4], the transmission queue distribution is represented by 3-dimensional joint distribution represented by the number of cells in the transmission queue, the number of short packets in the cell assembly queue, and phase of the arrival process of the short packets.

Another approach is that the output process of AAL2 multiplexing queue is modelled as sum of n-deterministic sources. Then, this output process applies into the $n \cdot D/D/1$ queue as shown in [5, 6]. In this case, it is hard to evaluate the performance and internal parameter values of AAL2 multiplexer, such as TL (Time Limitation) and PFCR (Partially Filled Cell Ratio). In this paper, we derive the departure process of AAL2 multiplexer. By doing so, we can establish the arrival process of the transmission queue. Therefore, we may consider only transmission queue to analyze the performance of AAL2. Furthermore, using the independence approximation which assumes that transmission and multiplexing queues are independent, equivalent 1-dimensional state space model is derived in terms of ATM cells in the transmission queue.

The paper is organized in the following manner. In Sect. 2, system model with continuous time Markov chain is explained. In Sect. 3, we analyze the stationary distribution of proposed model. In Sect. 4, we investigate some parameters of interest with numerical results in Sect. 5. Finally, conclusions are presented in Sect. 6.

2. System model

ATM Adaptation Layer 2 (AAL2) allows multiplexing of several AAL2 connections in an ATM virtual channel connection (VCC). The multiplexing procedure depends on several parameters, such as payload, packet length and the predefined expiry time limitation (TL). In this section, we establish a relation among these parameters.

Our analysis model is shown in Fig. 1. In AAL2 multiplexer, when a short packet arrives, a timer is set. If the time exceeds a maximum multiplexing waiting time TL, the short packet is sent to the transmission buffer. If the length of a set of short packets is shorter than 48 octets including the CPS (Common Part Sublayer) packet header, then the remainder of CPS payload is padded with null

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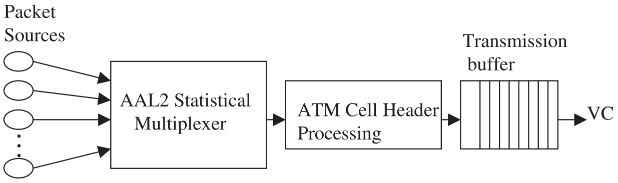

Fig. 1. Analysis model.

data. Whereas, if the time is less than the TL and accumulative total length of short packet is shorter than 48 octets, the multiplexer waits for the next short packet. Thus, the multiplexer checks up two multiplexing conditions which are

- Expiry of the TL (maximum waiting time to complete multiplexing) time.
- Accumulative CPS-packet length is greater than 47 octets.

Let's denote by l_i the accumulative length of CPS-packets at ith arrival, and by T the predefined time limitation value. Assume that inter-arrival time is exponentially distributed with mean λ. Total waiting time of ith CPS-packet arrival time x_i would be Erlangian. Then, above conditions are described as follows:

Condition 1:

$$Pr[x_i \le T] = \int_0^T \lambda e^{-\lambda t} \frac{(\lambda x)^{i-1}}{(i-1)!} dx. \tag{1}$$

Condition 2:

$$Pr[l_i \le 47] = \int_0^{47} f_{L_1}(l) * f_{L_2} * \cdots * f_{L_i} dl \tag{2}$$

where $*$ denotes the convolution and $f_{L_i}(l)$ is the pdf of short packet's length in the ith phase.

In order that multiplexing is in progress, conditions 1 and 2 should be satisfied. After that, multiplexer waits the next CPS-packet. This procedure is depicted in Fig. 2. Thus, multiplexing transition probability (β_i) can be expressed as

$$\beta_i = Pr[x_i \le T] \cdot Pr[l_i \le 47]. \tag{3}$$

To calculate the probability of second term in Eq. (3), we assume the packet length is fixed and heavy load condition. Let's denote by r the number of CPS packets in an ATM cell (i.e., Multiplexing gain of AAL2), which is defined as

$$r = \left\lceil \frac{47}{l_p + 3} \right\rceil \tag{4}$$

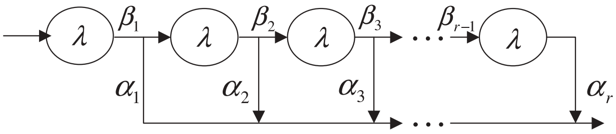

Fig. 2. Coxian model with β_i given by Eq. (5).

where $\lceil z \rceil$ denotes the smallest integer that is larger than or equal to z and l_p is the fixed short packet length. In steady state, multiplexing of the r-th arrival CPS packet is terminated by accumulating the ATM cell length. Therefore, Eq. (3) can be represented as

$$\beta_i = \begin{cases} 1 - \sum_{k=0}^{i-1} \left(\frac{e^{-\lambda T} (\lambda T)^k}{k!} \right) & i < r, \\ 0 & i \ge r. \end{cases} \tag{5}$$

where

$$Pr[l_i \le 47] = \begin{cases} 1 & i \le r, \\ 0 & i > r. \end{cases} \tag{6}$$

From Fig. 2, we can establish the departure process of AAL2 CPS. At each arrival time of ith CPS-packet, CPS-PDU is launched with probability $1 - \beta_i$ and multiplexing goes on with probability β_i. Therefore, the output process of AAL2 multiplexer can be modeled as the r-stage Coxian. The LST of probability density function of r-stage Coxian distribution [11] is represented by

$$\begin{aligned} A(s) &= \sum_{i=1}^{r} \alpha_i \prod_{j=0}^{i-1} \beta_j \left(\frac{\lambda}{s+\lambda} \right)^i \\ &\equiv \sum_{i=1}^{r} \kappa_i \left(\frac{\lambda}{s+\lambda} \right)^i \end{aligned} \tag{7}$$

where $A(s)$ means arrival process and $\beta_0 \equiv 1$. For simplicity, we will denote the $\kappa_i \equiv \alpha_i \prod_{j=0}^{i-1} \beta_j$.

3. Analysis

When the service time of the transmission queue has the exponential distribution with mean μ, it is possible to model 2 dimensional process (k, i) with Markov chain depicted in Fig. 3. For each node (k, i) represent the number of ATM cell in transmission queue and the number of

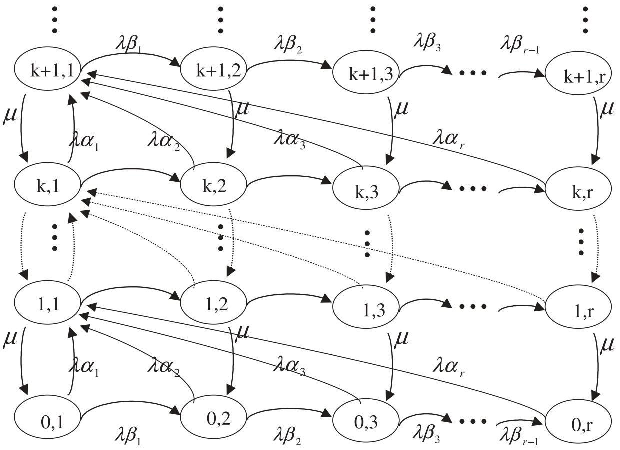

Fig. 3. Transition model of AAL2.