The Relation of CLR and Blocking Probability for CBR Traffic in the Wireless ATM Access Network

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ABSTRACT

In this paper it is focused on the relation between CLR (Cell Loss Ratio) and blocking probability, GoS (Grade of Services) parameters in the wireless ATM (Asynchronous Transfer Mode) access network which consists of access node and wireless channel. Traffic model of wireless ATM access network is based on the cell scale, burst scale and call connection level. The CLR equation due to buffer overflow for wireless access node is derived for CBR (Constant Bit Rate) traffic. The CLR equation due to random bit errors and burst errors for wireless channel is derived. Using the CLR equation for both access node and wireless channel, the CLR equation of wireless ATM access network is derived. The relation between access network CLR and blocking probability is analyzed for CBR traffic.

key words: ATM, CLR, CBR, blocking probability

Ⅰ. Introduction

ATM network will have an important role in the future evolution of global communication networks. Wireless ATM access network is considered as a wireless access network to interconnect the mobile users to the ATM network. In other words, wireless ATM access network architectures focus on the wireless extension of the B-ISDN terminals for seamless ATM connection.

In this paper it is focused on the relation between CLR and blocking probability in the wireless ATM access network which consists of access node and wireless channel. Wireless ATM access network is surveyed in section 2 and its CBR traffic model is described in section 3. In section 4, the CLR equation due to buffer overflow for wireless access node is derived for CBR traffic and the CLR equation due to burst errors for wireless channel is derived. Using the CLR equation for both the access node and the wireless channel, the CLR equation of wireless ATM access network is derived and finally the relation between CLR and blocking probability is analyzed. and the paper closes with the remarks in section 5.

Ⅱ. Wireless ATM access network

Wireless ATM access network is considered as a wireless access network to interconnect the mobile users to the ATM network. But there are some problems about packet mode information transport in the wireless environment, which is characterized by unreliable sharing access with finite resource and mobility. So modified or enhanced functionalities of the B-ISDN UNI, such as ATM and AAL layer protocols, are suggested to improve the wireless connectivity, which includes error control to improve the error performance and mobility support. Convolutional channel coding scheme is particularly considered to meet service requirements as shown in table 1(1). The ATM Forum Wireless ATM group has proposed a WATM system reference model(2). This model specifies the signalling interfaces among the mobile terminal, wireless terminal adapter, wireless radio port, mobile ATM switch and non-mobile

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ATM switch. It also specifies protocol layering architecture of the user and control planes.

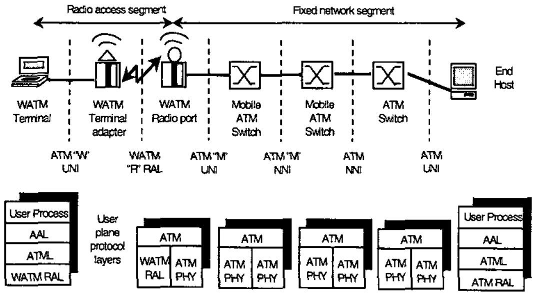


Fig. 1 The reference configuration of wireless ATM network.

Table 1. CLR performance requirements for ATM traffic.

items	ITU-T I.356 (end-to-end cell transfer performance)	Akira paper (wireless access link)
Bit rate (Mbit/s)	all bit rates	all bit rates
CLR	3×10^{-7}	1.5×10^{-8}

Ⅲ. CBR traffic model analysis for wireless ATM access node

3.1 Background

We can extend the flow of calls in a circuit switched network to consider the flow of cells through an ATM buffer. The time between arrivals (calls or cells) is given by a negative exponential distribution, that is to say, arrivals form a Poisson process. But, although the same source model is used, different types of behaviour are being modelled. In a ATM network, the focus is at the level below the call time scale, the characteristic behaviour of the service as a flow of cells. So three different time scales of activity are considered. That is, cell scale, burst scale and call connection level must be considered in a ATM switched network(4). Cell scale is focused on the behavior of cell generation at the lowest level and concerned with the time interval between cell arrivals. Burst scale is focused on the behavior of a transmitting user, characterized as a cell flow rate, over an interval during which that rate is assumed constant. In the connection level, set-up and clear events delimit the connection duration, which is typically in the range 100-1000 seconds. table 2 shows three time scale levels.

Table 2. Time scale level

levels of traffic behaviour	Stochastic phenomenon	Stochastic model	Traffic loss
cell scale	Statistical cell multiplexing generated from various source	Queue and population model	Cell loss
burst scale	Statistical multiplexing of a packet or packet group	Queue and population model	Cell loss
call connection scale	Call connection	population model (Erlang)	Call blocking

In ATM not only do connections contest, and may be made to queue, but each accepted connection consists of a stream of cells and these also must queue at the nodes as they traverse the network. we will use a queue then as a mathematical expression of the idea of resource contention in figure 2. There are two elements of queueing behavior in the performance analysis of ATM networks : the cell scale and burst scale components. But, for a mix of CBR traffic, only the cell scale component is present. Thus, we can evaluate the cell loss from a finite buffer for CBR traffic sources.

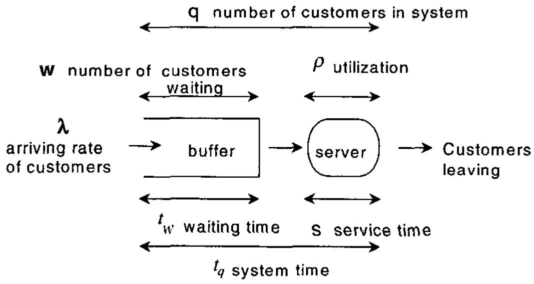
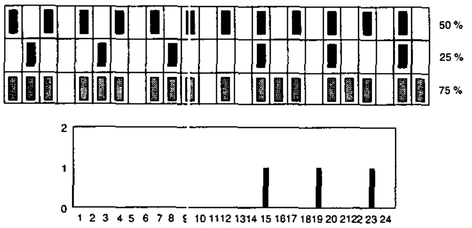


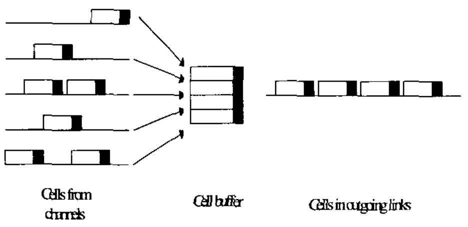
Fig 2. Queueing system.

3.2 Cell scale queuing behavior

Cell scale queueing occurs with CBR traffic when two or more cells arrive during a time slot. Cell scale queueing analysis quantifies the effect of having simultaneous arrivals according to the relative phasing of the CBR streams, so we define simultaneity as being within the period of one cell slot. When a large collection of CBR voice sources all send their cells to a single buffer, it is reasonably accurate under certain circumstances to model the total cell arrival process from all the voice sources as a Poisson process. Principle and modeling of cell scale queueing are shown on fig. 3.



(a) Principle of cell scale queueing



(b) Modeling of cell scale queueing

Fig. 3 Cell scale queueing

3.3 Call connection level

We consider two major systems, LCC (Lost Call Cleared) systems and LCD (Lost Call Delayed) systems for connection performance evaluation. In LCC systems which can be applied to ATM networks as shown in fig. 4, queueing is not provided for call requests, calls are assumed to arrive with a Poission distribution, and it is further assumed that there are a nearly infinite number of users. The Erlang B formula describes the GoS as the probability that an arbitrary user will experience a blocked call in a LCC system. It is assumed that all blocked calls are instantly returned to an infinite user pool, and may be retried at any time in the future. The time between successive calls by a blocked user is a random process and is assumed to be Poisson distributed.

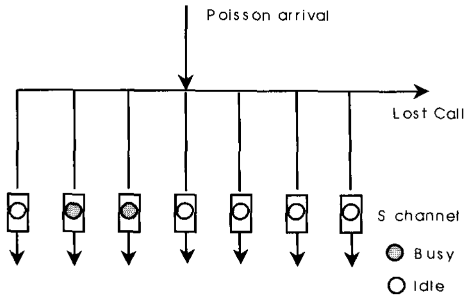


Fig. 4 LCC system model with infinite input

LCC system model with infinite input can be described by a Markov chain representation of a system with s channels. For example, the probability that there will be a change from 0 channel to 1 channel in use is given by λdt. On the other hand, if 1 channel is in use, the probability that the system will transit to 0 used channel is given by μdt. Similarly, the likelihood that the system will continue to use 1 channel is given by $1-\lambda dt-\mu dt$. All of the outgoing probabilities from a certain state sum to 1. The number of busy channels is equal to the number of busy users, and the probability of blocking is given as

$$B(s,a) = \frac{\frac{a^s}{s!}}{\sum_{k=0}^{s} \frac{a^k}{k!}} \qquad (1)$$

where s is the number of channels, and a is the total offered load to the system.

Ⅳ. The relation analysis of GoS parameter in the wireless ATM access network

4.1 The derivation of CLR and blocking probability

The CLR of wireless ATM access network (CLR_T) is related to the CLR due to buffer overflow (CLRo) and the CLR due to the non-ideal physical channel (CLRc). The CLR_T can be estimated as $CLR_T = CLRo + (1-CLRo)CLRc$. The cell loss ratio resulting from buffer overflow and the cell loss ratio resulting from bit error rate of physical layer are two independent processes.

$$CLR_T = CLRo + (1\text{-}CLRo)CLRc \tag{2}$$

For a CBR traffics, only the cell scale queueing is present except burst scale queueing in the access node. The ND/D/1 queue is a basic model for CBR traffic where the input process comprises N independent periodic sources, each source with the same period D. The CLR is approximated by the probability that the queue exceeds a certain buffer size x(4).

$$\begin{aligned} CLRo = & \sum_{n=x+1}^{N} \left\{ \frac{N!}{n!(N-n)!} \left(\frac{n-x}{D}\right)^n \right. \\ & \left. \times \left[1-\left(\frac{n-x}{D}\right)\right]^{N-n} \frac{D-N+x}{D-n+x} \right\} \end{aligned} \tag{3}$$

Assuming that both error bursts and errors in a burst are Poisson distributed, we get the Neyman-A contagious model in the wireless channel as shown (4). In this case, $P_B(n)$ is the probability that n errors occur in an interval of h bits when the mean error burst length is b and p denotes the bit error rate at the output of decoder(5,6). The subscript B denotes burst errors.

$$P_B(n) = \frac{b^n}{n!} \exp\left(\frac{-hp}{b}\right) \sum_{j=0}^{\infty} \left(\frac{hp}{b} \exp(-b)\right)^j \frac{j^n}{n!} \tag{4}$$

The CLR due to the non-ideal physical channel (CLRc) is represented in (5). The code rate of 4-ary(M =4) convolutional code is r=1/2, constraint length is ν=7 and the Viterbi decoder is used. p is the bit error rate at the output of Viterbi decoder and p_e is the bit error rate at the output of QPSK demodulator(7,8,9). Wireless channel is assumed to be a Rayleigh fading channel.

$$\begin{aligned} CLRc &= 1 - P_B(0) - P_B(1) \\ &= 1 - \exp\left(-\frac{16p}{b}\right) \\ &\quad \times \left[1 + \frac{(1+b)16p}{b} \exp(-b)\right] \\ p &\le 1/2(7d^7 + 39d^8 + 104d^9 + 352d^{10}) \\ d &= 2\sqrt{\frac{p_e(1-p_e)}{M-1}} + \left[\frac{M-2}{M-1}\right]p_e \\ p_e &= \frac{1}{2}\left[1 - \frac{1}{\sqrt{1+\frac{2}{\gamma}}}\right] \end{aligned} \tag{5}$$

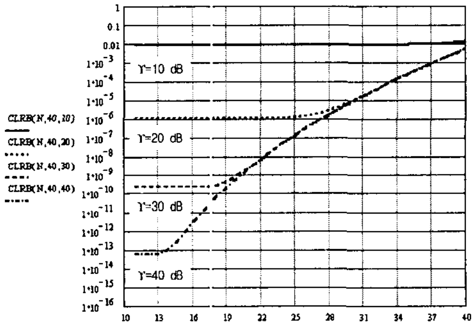
An important GoS parameter, in addition to cell loss, is the probability of a connection being blocked. This is very much dependent on the CAC algorithm and the characteristics of the offered traffic types. If we restrict the CAC algorithm to one that is based on limiting the number of connections admitted, then we can apply Erlang's lost call formula to the situation as shown in (1).

4.2 Relation analysis between CLR and blocking probability

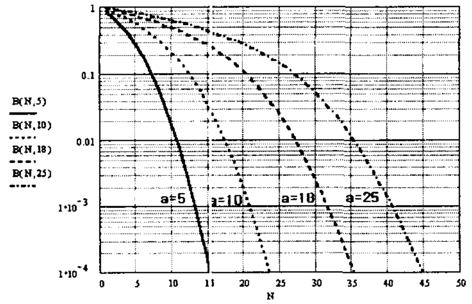
CLRB (N, D, γ) curve shows how the cell loss ratio varies with the maximum number of connections for different signal to noise ratio as shown in Figure 5(a). B(N, a) curve shows how the connection blocking probability varies with the maximum number of connections for different offered traffic intensities as shown in Figure 5(b)(4,10,11) . From the two curves described in Figure 5, The relation between CLR and blocking probability is derived for the following parameter.

- a buffer capacity(x) : 10 cells
- the number of slots between arrivals(D) : 40
- mean error burst length(b) : 6
- cell slot rate(C) : 4,528 cell/sec
- signal to noise ratio(γ) : 10, 20, 30, 40dB
- the code rate of 4-ary(M =4) convolutional code(r) : 1/2
- constraint length of 4-ary convolutional code(ν) : 7

Suppose we have CBR sources of cell rate 113 cell/sec being multiplexed over a 2.048 Mbit/sec link, with a CLP requirements of 10^{-7}. This gives a value of 40 for D, and from Figure 5(a), when the signal to noise ratio(γ) is 10 dB and 20 dB, a CLP requirements of 10^{-7} are not reached in all cases. But, when the signal to noise ratio(γ) is 30 dB, a CLP requirements of 10^{-7} are reached under a certain circumstances. In other words, when a CLP is 10^{-7} with the signal to noise ratio(γ) curve of 30 dB, the maximum number of call connections is near 25. Now that we have a figure for the maximum number of connections, we can calculate the offered traffic at the connection level for a given probability of blocking. From Figure 5(b), we find that for 25 maximum connections and a connection blocking probability of 0.03, the offered traffic intensity is 18 Erlangs. Note that the mean number of connections in progress is numerically equal to the offered traffic, i.e. 18 connections. The cell loss probability for this number of connections can be found from Figure 5(a). It is below the CLP requirements of 10^{-7}. In conclusion, we have seen that the relation between cell scale queueing level and call connection level can be derived. we have also seen that when the connection blocking probability requirements are taken into account, the actual cell loss probability can be rather lower than that for the maximum allowed number of connections.



(a) CLR, given D cell slots(40) and signal to noise ratios (γ = 10, 20, 30, 40 dB)



(b) Blocking probability, given maximum connections and offered traffic

Fig. 5 The relation between blocking probability and CLR

V. Remarks

In this paper we have seen the relation between CLR and blocking probability in the wireless ATM access network. CBR traffic model of wireless ATM access network is based on the cell scale queueing and call connection level. In other words, both the cell scale and the call connection level is only considered and the burst scale is not considered for a mix of CBR traffic. The CLR equation due to buffer overflow for wireless access node was derived for CBR traffic and the CLR equation due to burst errors for wireless channel was derived. Using the CLR equation for both access node and wireless channel, the CLR equation of wireless ATM access network was derived. And finally the relation between CLR and blocking probability was analyzed for the CBR traffic in the wireless ATM access network. These results can be utilized for designing the practical wireless ATM access networks.

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