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Title : **Modification of the CCITT/MPEG ATM cell loss model**
Purpose : Proposal

1 Introduction

Cell loss can occur unpredictably in ATM networks. To allow the simulation of the effects of bursty cell loss on video coding, CCITT proposed a method of simulating cell loss which was adopted by MPEG[1]. A specification for a packetized bit stream and a model of bursty cell loss were defined. For a given average cell loss rate and a given mean length of bursts of lost cells, it is completely known which cells will be lost when this model is adopted.

A random number generator was specified to make the simulation of cell loss machine and programming language independent. However, this random number generator is not perfectly random. To reduce the influence of the characteristics of the random generator on the simulation of cell loss when the priority bit is used, it was proposed to use separate cell loss generators for each of the priorities.

In this document, it is pointed out that the characteristics of the random generator also influence the simulation of cell loss when cells of only one priority are used. A modification to the cell loss model is proposed to improve the simulation of cell loss.

2 Random number generation

In the CCITT/MPEG ATM cell loss model, random numbers are generated by use of a 31 bit shift register which cycles pseudo-randomly through $(2^{31} - 1)$ states (the value of zero is never achieved). The shift operation is defined by the following pseudo-Pascal code:

```
DO 31 times
Begin
   Bit30          := (ShiftRegister & 2^30) DIV 2^30;
   Bit25          := (ShiftRegister & 2^25) DIV 2^25;
   ShiftRegister  := (2*ShiftRegister MOD 2^31) + (Bit30 XOR Bit25);
End
```

To generate a random number, the shift register is first shifted as above and then divided by $(2^{31} - 1)$. Separate random number generators are used for low and high priority cell loss. To initialize the shift registers, they are set to a value of 1 and are then shifted 100 times (Note that the initialisation is defined as 100 *shifts*, not as 100 *shift operations*, what is equal to 100 * 31 shifts).

At the last meeting of CCITT SG XV/1, it was decided to change the number of shifts for the initialisation from 100 times to 10000 times. It was found out [2] that otherwise the resulting sequence of random numbers had a low mean value, probably due to the large number of zeroes still in the shift register. The resulting low random numbers would have caused the actual cell loss rate to be higher than the desired cell loss rate.

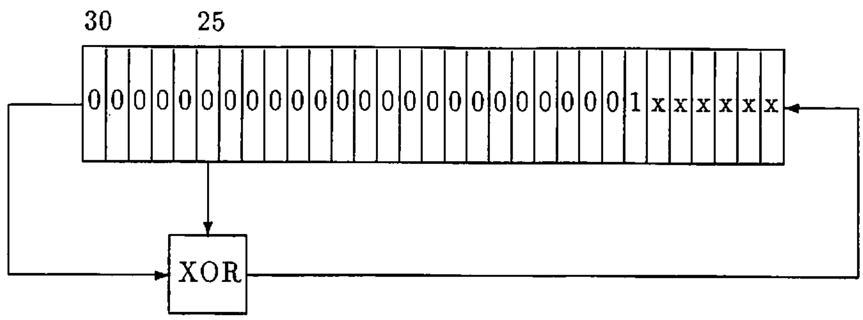

Figure 1: *Shift register of the random number generator.*

3 Influence of random number generator on minimum burst length

The CCITT/MPEG ATM cell loss model requires two input parameters: the average cell loss probability P and the mean burst of consecutive cells lost B. From these parameters is calculated the probability that a cell is lost given that the previous one was lost (Pl = 1 - 1/B) and the probability that a cell is lost given that the previous one was not lost (Pn = P / B * (1 - P)). For each ATM cell, the contents of the shift register is compared with Pn or Pl, dependent on the previous cell being lost or not. However, when only one shift register is used for the comparison with Pn as well as with Pl a strong relationship exists between the characteristics of the random number generator and the minimum burst length of consecutive cells lost.

When no cell loss has occured, for each cell the contents of the shiftregister is compared with Pn. When for a certain cell the contents of the shiftregister is larger than Pn, ATM cell loss occurs. As Pn will be usually small, the shift register will then contain many zeroes at the left.

For the next cell, a new random number will be generated. The contents of the shift register is shifted 31 times as defined in the pseudo-code. So, all bits of the new random number in the shift register are a result of the XOR operation of Bit30 and Bit25. Note that again many zeroes will appear at the left of the register, because (0 XOR 0 = 0). The position of the left most non-zero bit of the new random number will be 30 - 25 = 5 bit positions to the left compared to that of the previous random number. **So, the new random number will be equal to about $2^5 = 32$ times the previous random number.**

The new random number will now be compared with Pl instead of Pn. As Pl is usually much larger than Pn, the probability that the new random number is smaller that Pl can be very high. This makes the occurence of long bursts more likely. Dependent on the values for the input parameters P and B, a burst of only one or a few consecutive cells lost may even be impossible. The equation for the minimum burst length is:

$$B_{min} = \frac{(int)^2 log(Pl') - (int)^2 log(Pn') - 1}{5} + 1 \qquad (1)$$

with Pl' = Pl * $(2^{31} - 1)$ en Pn' = Pn * $(2^{31} - 1)$.

For an average probability of cell loss of 10^{-3} and a mean burst length of 2 as input parameters, $B_{min} = 2$. For an average probability of cell loss of 10^{-8} and a mean burst length of 2 as input parameters, $B_{min} = 6$. However, the burst length should be determined only by the input parameters and by the cell loss model, not by the random number generator. In the next paragraph, a proposal is made to overcome this problem.

4 Proposal

The effect described in the previous paragraph influences the characteristics of the simulated ATM cell loss. Usually, the mean burst length will be too high. However, the number of bursts is usually quite accurate. The result is that the total number of lost cells will be too high. To overcome this, the ATM cell loss simulation model should be slightly adapted.

Proposal 1: use 1000 shifts instead of 31 for the generation of each random number

With this change, the results of the ATM cell loss model will be better, but not perfect. Therefore, we propose to add a statement to the model describing its accuracy limitations:

Proposal 2: Add to the description of the model:
"With respect to the results of this model, it must be taken into account that this model has a limited accuracy. In particular when the expected number of cells lost is less than 100."

5 Experiments and Results

The CCITT/MPEG ATM cell loss model was used to simulate cell loss in a sequence of 33733 ATM low priority cells. For the initialisation of the shift registers, 10000 shifts were used. The simulations were performed twice: with 31 shifts and with 1000 shifts for the calculation of each random number. The results are shown in table 1.

It appeared that the results for the modified model are closer to the input parameters than the results for the original model. Especially when a mean burst length of 2 is used as input parameter, the use of 1000 shifts for the generation of a random number leads to improved results. However, for P = 0.001 the adapted model seems to produce bursts that are shorter than desired, although the error is less than with the current model. The simulations were repeated with 10000 shifts between random numbers but this did not improve performance. Increasing the total number of cells did not significantly affect the results either.

6 Conclusion

The CCITT/MPEG ATM cell loss model was briefly introduced. It was explained that with this model small burst lengths are not possible in some cases, dependent on the input parameters. A modification to the ATM cell loss model was proposed, which improves the simulation results, especially for low mean burst lengths. As even the adapted model does not guarantee cell loss statistics exactly as desired, it was proposed to add a statement to the model describing its accuracy limitations.

7 References

[1] CCITT SGXV, WP XV/1, AVC-205, Cell loss experiment specifications.
[2] COST 211 ter SIM, Document No.92/69, MPEG Test Model cell loss experiment.

input parameters	results (CCITT model)	results (modified model)
P = 0.1	0.101	0.099
B = 2	2.10	2.02
P = 0.01	0.012	0.009
B = 2	2.98	1.91
P = 0.001	0.002	0.0005
B = 2	3.45	1.42
P = 0.1	0.107	0.097
B = 4	4.53	4.08
P = 0.01	0.012	0.009
B = 4	5.66	3.70
P = 0.001	0.001	0.0006
B = 4	6.25	3.33

Table 1: *Results of the CCITT/MPEG ATM cell loss model with 31 and with 1000 shifts per generation of a random number*