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MANAGING THE TRAFFIC STREAMS IN AN OPTIMAL WAY

Asynchronous multiplexing in ATM means that data cells are not transmitted within fixed time frames. In an ATM network, the ATM connections are monitored at the network input in respect to the accumulation of ATM cells. To avoid exceeding a specified cell loss rate, measures are taken to eliminate an accumulation of ATM cells. This contribution explains the internationally standardized measure for ATM cell accumulations (cell delay variation) which is to be applied and states the limiting values to be tolerated within the ATM cross-connect network of the Swiss Telecom.

Like every other telecommunication network, an ATM network consists of network nodes and transmission links. The main task of network nodes is to link the traffic streams arriving at

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their inputs in a correct way to their outputs. Thereby, traffic links can only handle as many connections as their capacity allows. For connection-oriented networks such as ATM networks, a test is performed during the connection buildup phase at every transmission link in respect to the capacity that is available for a given new connection. If the capacity is not sufficient, another transmission link is searched or in the case that none is available, the connection is rejected. Within the Swiss ATM cross connect network, connections are managed by a dedicated management system. In a synchronous multiplexing system

such as is known in digital telephone networks or in the narrowband ISDN, the information per individual connection on a transmission link is transmitted always at the same position of a periodic multiplexing frame. Through this, the number of transmitted octets per multiplexing frame is constant and their sum corresponds to the capacity of the transmission link.

With ATM, the multiplexing is asynchronous which implies that information packages (cells) of individual connections are not transmitted within fixed frames. To avoid the acceptance of too many connections on transmission links and through this, possibly unacceptable transmission losses, a measure for the capacity is required also for ATM links. Such a measure has been defined by the International Telecommunication Union (ITU) at the end of 1994 and is designated as the 'peak cell rate' [1].

Characterizing ATM links through the peak cell rate

The capacity may not be sufficient any more if cells are transmitted with very high rates on several connections being present on an individual transmission link. Under such circumstances, cells are lost or they must be stored temporarily during such peak loads. Besides of the costs involved for corresponding memories, an additional problem arises concerning an excessive transmission delay which may be detrimental for real-time applications such as video conferences. Due to this constraint, relatively small buffer memories are applied in ATM networks (order of magnitude of 100 cells).

To ensure a good network quality for all customers, an agreement is to be made per customer in respect to his prospective traffic. The compliance with the agreement will then be monitored in the interest of all customers and traffic peaks being incompatible are eliminated. This function is called 'usage parameter control'.

Also, in a situation where cells are sent in a purely periodical way from given ATM sources¹, variations may occur in respect to the time differences at the network input between cells of a given source. This is especially the case if at a subscriber line, several ATM connections are multiplexed. Such a situation is represented in *Figure 1*.

The cell streams of two ATM sources are given to a multiplexer. The multiplexed data stream is then available at the output (*Fig. 1*). All three interfaces use the same cell clock, but with

¹ An ATM source is defined as a terminal equipment that includes an ATM interface or a corresponding adaptation device implementing the required adaptation of a signal of differing format to an ATM cell structure.

different phase. The sources 1 and 2 present cells at constant time spacings. By the adaptation process at the outputs of the sources, unequal time spacings result between cells. The fluctuations of the spacings are even larger at the output of the multiplexer since for cells that arrive just in sequence at the inputs, the requirement occurs that one of them must wait (the multiplexer transmits the cells in the order of their arrival). Therefore, cells follow each other from source 1 just in sequence whereas this was not the case initially, at the output of source 1. Due to such effects, the usage parameter control must tolerate fluctuations of the cell arrival delay spacings. In [1], such a monitoring algorithm is described. It is based on the peak cell rate ($1/T$) and the cell delay variation tolerance (τ). The cell delay variation of the k th cell (y_k) is defined as the difference between a reference arrival time (c_k) and the arrival time of cell (a_k) [2]:

$$y_k = c_k - a_k.$$

The next reference arrival time is obtained by increasing the larger of the two reference arrival times (arrival time of the preceding cell or reference arrival time) by the peak emission interval T (Fig. 2):

$$c_{k+1} = \max(a_k, c_k) + T$$

The agreement is satisfied if the cell delay variation does not exceed the given value τ .

Figure 2 shows the way in which the cell delay variation (y_2, y_3, y_4) increases due to the fact that cells 1 to 4 succeed each other at time intervals shorter than the peak interval T . For the case of cell 5 however, the time difference from cell 4 is much larger than T and the cell delay variation y_5 becomes negative.

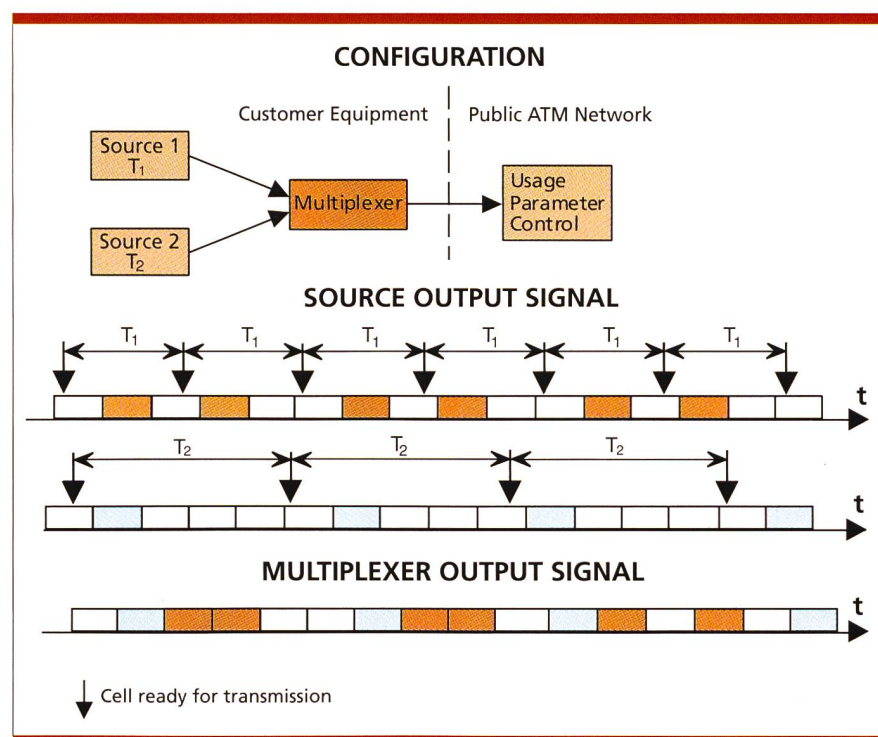


Fig. 1. Multiplexing of the cell streams of two ATM sources, presenting cells at constant time spacings.

Figure 3 shows the effect of two different peak cell rates ($1/T_1$ and $1/T_2$) on the cell delay variation. It can be seen that the cell delay variation is decreased by an increase of the peak cell rate.

The Swiss Telecom specifies the allowable cell delay variation (τ) at the network input. The compliance with the specification is continuously monitored by the usage parameter control system. Cells whose cell delay variation exceeds the value of τ are eliminated in the interest of ensuring the network quality for all other customers.

In network nodes of an ATM network, cells from different inputs and des-

tinated for the same output may arrive subsequently with very little or even no delay. By the phenomena of the kind demonstrated in Figure 1, bursts of cells may arrive at inputs of a network node leading to an even higher concentration of successive cells and resulting in a correspondingly higher cell concentration of a node output. Thus, to avoid exceeding the specified cell loss rate, buffer memories must be available in the network nodes to store such occurring cell bursts. The larger the cell delay variation at the network input of ATM connections, the higher the probability of overflow in the nodes. In the department of Research and Development of the Swiss Telecom, investigations have taken place about the tolerable amount of cell delay variation within the ATM network under the constraint of a specified cell loss rate. For this aim, the assumption was made that all sources send bursts of successive cells into the network (Fig. 4) where the phases of the periodic source signals are independent from each other. Considering the range of traffic characteristics accepted by the usage parameter control system, this case must be considered as very unfavourable and more usual character-

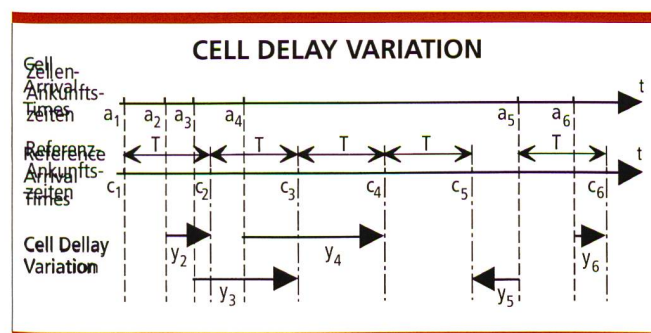


Fig. 2. Illustration of cell delay variation.

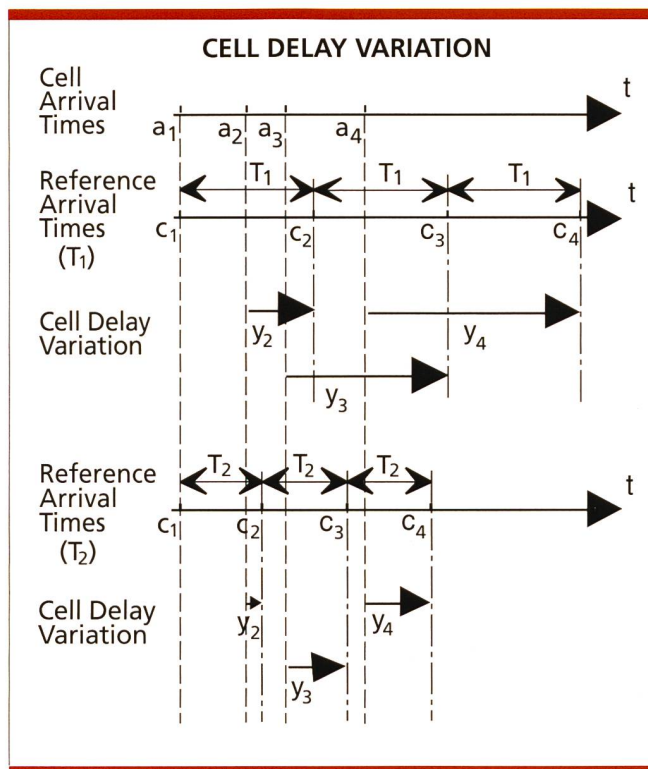


Fig. 3. Cell delay variation based on given cell arrival times, for two different peak cell rates ($1/T_1$ and $1/T_2$).

istics lead to rather smaller cell loss rates. The cell delay variation tolerance at the input of the ATM network was defined on the basis of these results.

Figure 5 shows the cell delay variation tolerance (τ) which is offered by the Swiss Telecom relative to the desired peak cell rate $1/T$ at the network input (provisional values). If the customer assures that his ATM connection satisfies the monitoring algorithm in [1] with values T and τ below the limiting curve, no cells are being eliminated in the Swiss ATM network.

It should be noted that the cell delay variation is a measure for the bursting of cells at a certain interface, but it is no measure for the delay fluctuations of cells of a connection through a network. In [2], a measure is defined for this latter case in addition to the cell delay variation: it is called the 2-point cell delay variation.

Aspects concerning the customer equipment

Determination of the peak cell rate

The tariff for ATM connections increases with the peak cell rate. The more regularly the ATM cells are transmit-

ted, the smaller is the required peak cell rate and thus the cost. If the specified cell delay variation cannot be met with a certain peak cell rate, the cell delay variation can be reduced by increasing the peak cell rate (Fig. 3). Although the cell delay variation tolerance decreases also with increasing peak cell rate, this reduction is smaller than that one of the resulting cell delay variation. In this way, a suitable peak cell rate can be found in cases where the fluctuation of the cell spacings is not exceedingly high (Fig. 6). If an ATM source is connected directly to the ATM network, the cell delay variation corresponding to the peak

cell rate may be exploited fully (Fig. 5). If several sources are multiplexed, the increase of the cell delay variation in the multiplexer must be considered however (Fig. 1).

It must be noted that due to special implementations of the ATM sources, fluctuations of the cell spacings may occur (e.g. through variations of the cell processing delay). It is therefore important to consider the cell delay variation when terminal equipment is acquired.

Services with constant bit rate

For services with constant bit rate, the time required for filling a cell is constant. A corresponding ATM source thus is expected to deliver cells with constant time spacings. Figure 6 shows the evaluation of a measurement of the cell delay variation of an adapter equipment for a constant bit rate of 2.048 Mbit/s (circuit emulation) in function of the peak cell rate applied. In the same figure, the cell delay variation specified by the Swiss Telecom from Figure 5 is indicated. As follows from this figure, a peak cell rate of at least 5750 cells per second is required for this arrangement. This value is about 5.5 % higher than would be required for a regular supply of cells since this equipment emits, the cells with relatively little regularity.

Data transmission

In data transmission, the information is normally transmitted in packets of variable length. In part, these packets may find their place within a few ATM cells. Often however, they require a large number of cells (e.g. an order of

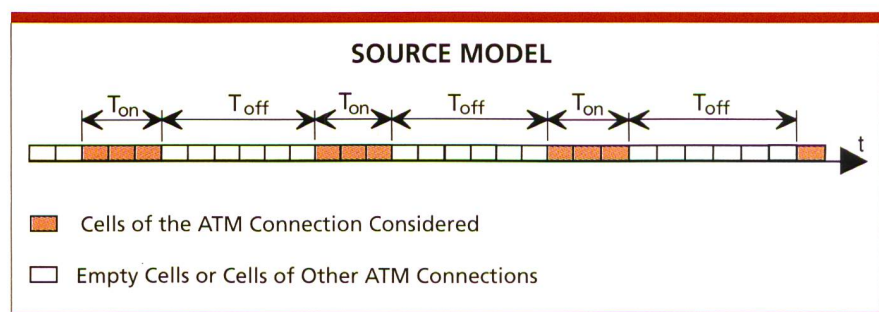


Fig. 4. Source model.

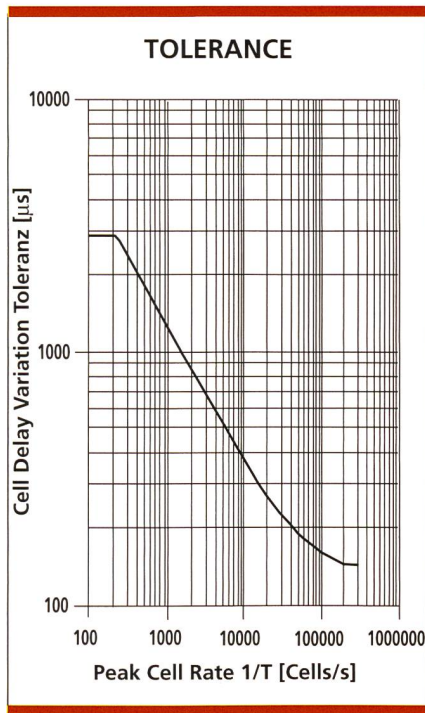


Fig. 5. Cell delay variation tolerance at the input of the Swiss ATM network in function of the peak cell rate (provisional values).

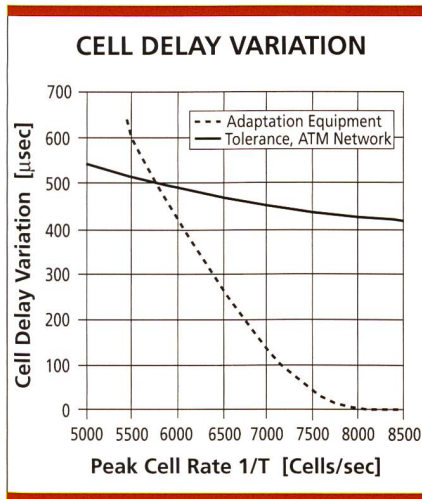


Fig. 6. Cell delay variation of an adaptation device for a constant bit rate of 2.048 Mbit/s (circuit emulation) in function of the peak cell rate applied and acceptable values within the Swiss ATM network.

magnitude of 100 cells). In the case where an adaptation device is used which sends the cells at high speed into the ATM network, a high peak cell rate may be required. For an economical transmission, it is in the interest of the customer that the adaptati-

on device achieves a cell transmission with a large spacing. For this purpose, a buffer memory is required. Such an adaptation of the stream of cells is called traffic shaping. Functionally, the process is represented in Figure 7. The peak cell rate $1/T$ is best chosen possibly small but large enough that the probability of overflow for the 'shaping buffer' is sufficiently small. This depends on the properties of the data traffic to be transmitted. Especially important are the statistics of the spacing of the packets as well as their lengths. A high peak cell rate is required if packets often immediately follow each other. The peak cell rate becomes especially large if for example the length of the packets to be transmitted is just one octet longer than the fixed cell packet capacity inherent of the ATM transport system since in this case, a new cell is required just for the additional octet.

Future possibilities

The descriptions so far are based on the assumption that on all transmission links of the ATM network, the sum of the peak cell rates of all connections on the link is always smaller than the cell rate of the particular ATM transmission link. The first applications of the ATM technology are mainly in the field of data communication. The transmission of data traffic leads to cell bursts corresponding to the data packets. However, data packets can also occur in bursts. This leads to the result that the peak value of the transmission rate becomes considerably larger than the average transmission rate. It is unsatisfactory for customers to pay for a peak rate that they rarely use. Thus, there are various methods being studied within the standardization bodies with the aim of a more efficient usage of the network. These methods are based on statistical multiplexing or on a feedback concerning the network load.

Statistical multiplexing

A methodology for statistical multiplexing of sources with variable bit rates has already been specified within the ATM forum [3] and will presumably be passed by the ITU during this year. Considering the procedure

in a somewhat simplified manner, a short-term average cell rate and the maximum length of the cell bursts (with peak cell rate) are agreed between customer and network operator, besides the peak cell rate already mentioned. These parameters are monitored with the aid of the usage parameter control system. Per transmission link, only that many ATM connections are accepted as the cell loss rate specification allows.

Since with this procedure, the average cell rate specification per ATM connection is satisfied besides the peak cell rate, more connections can be accepted per transmission link than for cases where only the peak cell rate specification is satisfied. The multiplexing gain is large for the case where the average cell rate of the connections is much smaller than their peak cell rate and where this again is much smaller than the cell rate of the transmission links. At a peak cell rate of 10 % of the cell rate of the transmission link, a multiplexing gain of about 2 is reached for the case where the ATM sources transmit at the peak cell rate during 5 % of the time and nothing during the rest [4]. This means that twice as many connections can be accepted per transmission link compared to the case where only the peak cell rate is considered. The resulting multiplexing gain therefore allows offering such connections at a lower tariff. As the example shows, this is true however only for connections with relatively low peak cell rate and also even lower average cell rates.

The functions necessary for statistical multiplexing (usage parameter control, call acceptance control) are already integrated within the cross connects of the Swiss ATM network. However, this is not the case yet for the service multiplexers. Service multiplexers featuring such integrated functions and which also convert data traffic into ATM cell streams in accordance with these functionalities (traffic shaping) are announced for a later point in time. The introduction of such a service is foreseen accordingly for the Swiss ATM network.

Available bit rate service

Under the definition 'available bit rate service' (ABR), studies are going on with the goal of better usage of the resources of an ATM network

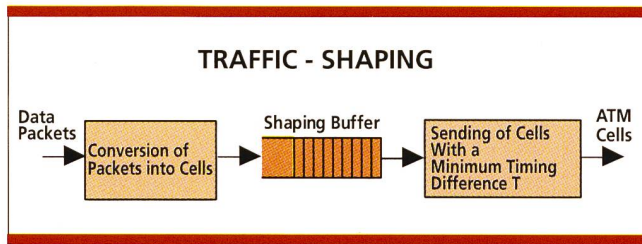


Fig. 7. Traffic shaping for data transmission over an ATM network.

under the conditions of quickly varying traffic by applying a flow control. The idea thereby is to decrease the traffic flow by reducing the capacity of connections which are not necessarily dependent on high transmission rates and short transmission delays (e.g. electronic mail, file transfer, etc.). Because these connections merely use the capacity remaining from other connections with higher priority, they could be offered at a lower price. Within the ATM forum, a specification is being developed for the interfaces between sources and networks as well as sinks and networks. It shall be passed in September 1995.

Because the functions necessary for ABR are not realizable by most of today's ATM network nodes, it can be predicted with high probability that this service will not be offered commercially before 1998. In addition, it is not clear at present if the capacity savings attainable will outweigh the higher cost of the various ATM hardware and also, how large the market will be for such connections.

Acknowledgement

The author would like to thank Mr. F. Wyler for providing the Figures 5 and 6.

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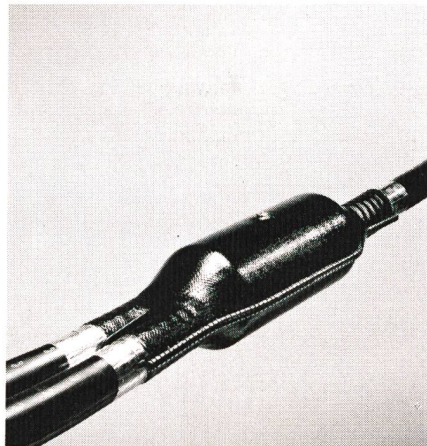
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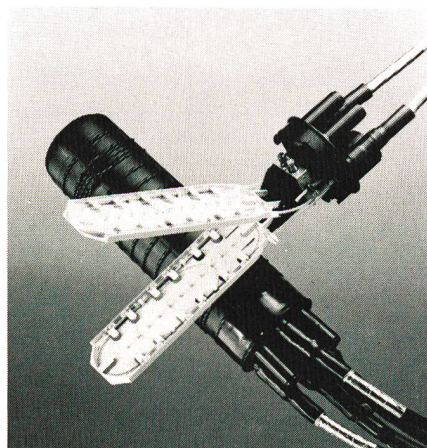
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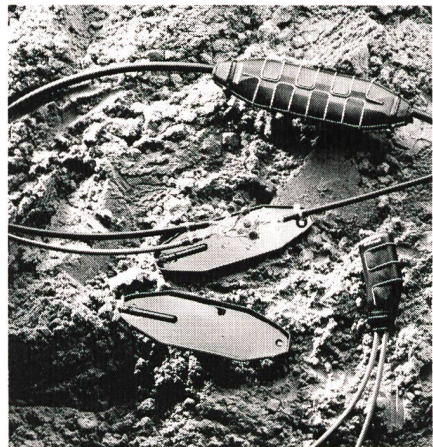
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