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EXAMPLE OF TRAFFIC SOURCE CHARACTERIZATION

# WHAT IS GOING ON THE NETWORK?

One of the problems we are facing on the information highways is the traffic characterization. How can we identify what is going on the network? How many ATM cells per second will be sent on a link? Will the cells be equally spaced, or will they come in bursts? What is the burst density? This is the type of questions we have to answer today when we are using the ATM technology.

first measurement set has been run using two DSUs connected back to back via an E3-PLCP link and two routers. During the second set of measurement, the DSUs were connected by an E3-G804 link to the ATM network.

## The traffic shape

In order to have a quick idea of the traffic shape, we first monitor the source with an ATM measurement equipment and record the cell arrival times. The result of the interarrival

Let us look for instance at an application like a file transfer. The first computer reads its disc: this involves CPU time, but also mechanical access to a device. Once read, the data is

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packed and sent across the network. On the other side the data has to be written on a medium again. Usually the time needed for the transfer is small in comparison with the disc access time. This results in a bursty traffic on the network.

We need to know how much bandwidth we shall reserve for such a connection to allow for a smooth transfer of good quality without wasting network capacity.

## Source and configuration

As an example, we will describe the different approaches used during a traffic source characterization of a LAN interconnection. The LANs are connected to the ATM network via Data Service Units (DSU). On the router side of the DSU, the link is an HSSI, whilst the ATM interface is an E3. For the measurement, two different configurations have been used. The

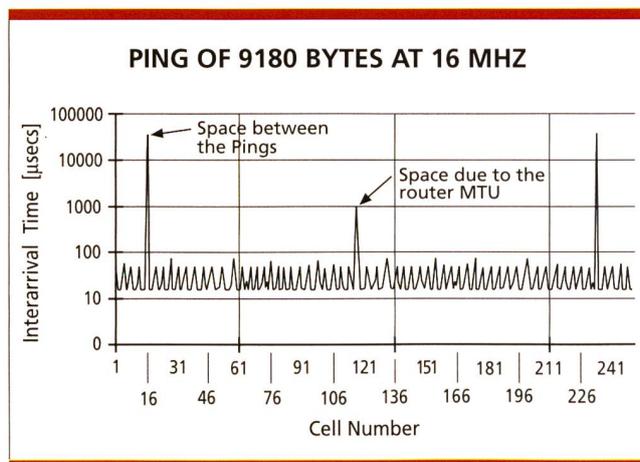


Fig. 1. Interarrival time of the cells during a ping of 9180 Byte at 16 MHz (214 ATM cells). The router is configured with a MTU of 4470 Byte.

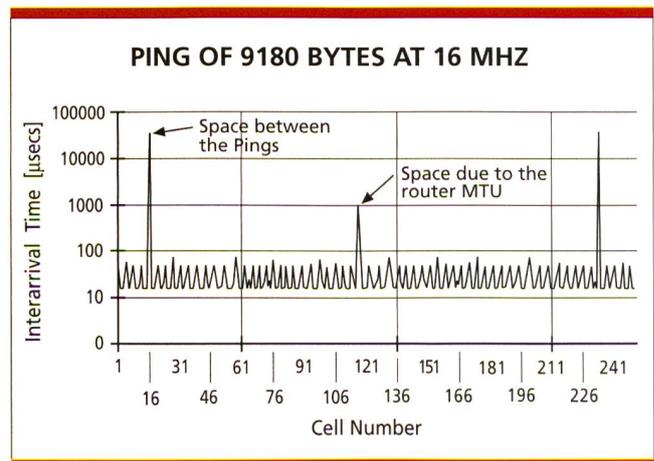


Fig. 2. Interarrival time of the cells during a ping of 9180 Byte at 16 MHz. Due to the DSU behaviour, the cells are packed in bursts of four.

time calculation (difference between two cell arrival times) is plotted in *Figure 1*.

On the x-axis of the diagram we display the cell number and on the y-axis the elapsed time since the last cell arrival, i.e.  $time(n) - time(n - 1)$ . That means, the greater the peak, the longer the space between two cells. We clearly see the space between two pings and a space due to the router MTU. (The MTU, Maximum Transfer Unit, allows the router to 'breathe' during a data transfer.)

If we enlarge the diagram and look closely into the ping packet, we discover that the DSU sends four cells back to back, followed by a silent gap (*Fig. 2*). We can deduce that this source behaves as a burst-dispatching source (BDS).

### Characterization methods

The speed on the HSSI interface may be defined by means of setting a clock rate. One of the goals of the characterization is to find out the peak cell rate needed on the ATM stream for different settings of the DSU clock rate.

To find out the relationship between the clock rate and the ATM bandwidth, the following approaches have been used:

- pure theoretical mapping of the DSU clock rate to the ATM cell rate
- calculation using the average measured interburst length
- study of the couple T (peak emission interval) and  $\tau$  (cell delay variation tolerance) on a recorded traffic
- measurement of the minimum possible bandwidth for a traffic between routers (ping)
- measurement of the minimum possible bandwidth for a traffic end to end, i.e. between workstations (file transfer application)

In addition, random tests have been carried out, using two other applications: NFS (Network File System) and the remote display by X11 protocol.

#### Approach 1: Pure theoretical mapping of the DSU clock rate to the ATM cell rate

This run is a pure theoretical approach. The traffic received from the router is mapped to ATM level, using

the SAR of AAL type 3/4. The SAR overhead consists of a header of 2 Byte and a trailer of 2 Byte. Adding then the 5 Byte used as ATM header, this leaves 44 Byte available for the CPCS-PDU. So the number of cells needed corresponds to the number of SIP-L3 PDUs, divided by the number of bytes available (i.e. 44), taking into account the fact that the number of cells used is modulo 44 plus one. This means that the peak cell rate may be expressed as follows:

$$PCR-1 = \text{number of SIP-L3 PDU} \times \text{int} \left( \frac{\text{SIP-L3-length}}{44} + 0.99 \right)$$

The number of SIP-L3 PDU per second depends on the DSU clock rate in the following way:

$$\text{number of SIP-L3 PDU} = \frac{\text{DSU clock rate}}{8 \times (\text{SIP-L3-length} + 6)}$$

So the peak cell rate may be declared, depending on the DSU clock rate as follows:

$$PCR-1 = \frac{\text{DSU clock rate}}{8 \times (\text{SIP-L3-length} + 6)} \times \text{int} \left( \frac{\text{SIP-L3-length}}{44} + 0.99 \right)$$

We see that the PCR depends on the SIP-L3-length. Let's assume that the minimum SIP-L3-length is 50 Byte. Taking in account the fact that 80 % of the SIP-L3 PDUs have a maximum length of 300 Byte, we can compute the formula in the range 50 to 300.

$$PCR-1 = \frac{\text{int} \left( \frac{\text{SIP-L3-length}}{44} + 0.99 \right)}{\text{DSU clock rate} \times \text{average}} \times \frac{1}{8 \times (\text{SIP-L3-length} + 6)}$$

This leads to the results for approach 1 as shown in *Table 1*.

#### Approach 2: Calculation using the average measured interburst length

*Figure 3* describes the configuration used. The monitor records the traffic and the arrival times of 500 cells, which are then analysed. We observe that the DSU sends four cells together, followed by a silent gap, depending on its clock rate. The formula gives the cell rate for a traffic composed by  $N_{on} + N_{off}$  cells. The value of the gap between bursts is an average of the gaps measured (*Fig. 4*).

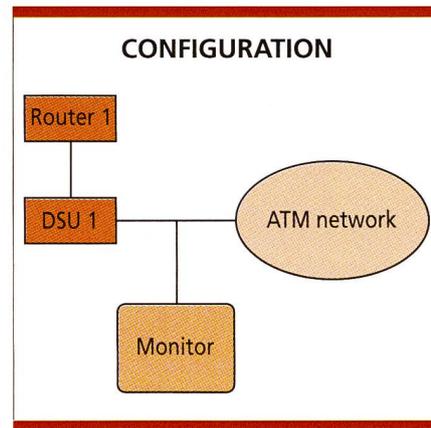


Fig. 3. Configuration approach 2.

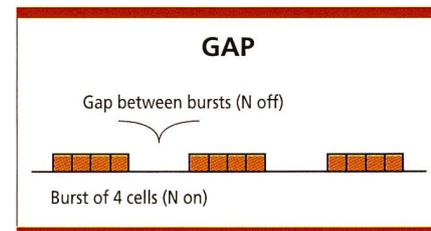


Fig. 4. Gap between bursts.

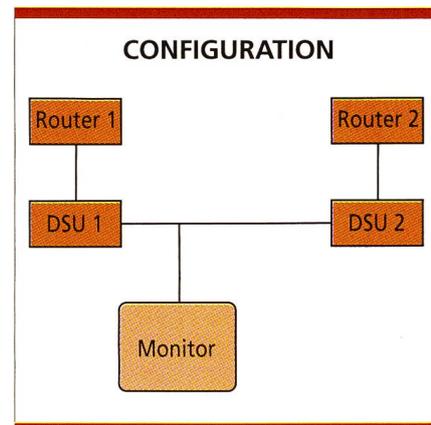


Fig. 5. Configuration approach 3.

The formula looks like:

$$PCR-2 = \text{link rate} \times \frac{N_{on}}{N_{on} + N_{off}}$$

This approach supposes that the traffic is very steady, i.e. that the burst-spacing functions of the DSU behave correctly. If the GBB (gap between bursts) varies, then either the CDV tolerance parameter or the bandwidth has to be increased.

For a clock rate of 2.5 MHz, the average gap measured was 41.57. This gives as peak cell rate of 7180 cps (*Table 2*).

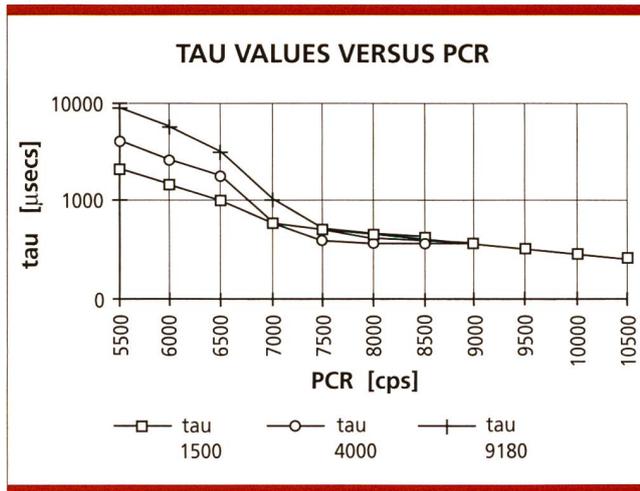


Fig. 6.  $\tau$  values versus PCR for different ping packet sizes (1500, 4000 and 9180 Byte) and for a DSU clock rate of 2.5 MHz.

The sample size is 13 1072 cells. On each sample we calculate then the valid couple  $(T, \tau)$  as follows: for a given  $T$  ( $1/PCR$ ) we search the minimum  $\tau$  value (CDV tolerance) for which no cell will be discarded by the policing. Please refer to the article on 'Traffic Concept in ATM Network' in this issue for a comprehensive description of the parameters  $T$  and  $\tau$ . The couple  $(T, \tau)$  are then plotted. The interesting part of the curve is when the PCR values are greater than the PCR found for the connections (see Table 3). The results being of the same shape for the different DSU clock rates, we give here an example for a clock rate of 2.5 MHz (Fig. 6).

The values plotted above can be read in Table 4.

As we can see, the value of  $\tau$  decreases with increasing PCR for the three datagram sizes. Finally, the three curves merge together. This behaviour has been confirmed for all the different DSU clock rates. We can suppose that when the curve of ping packet size 1500 Byte crosses the one of ping packet size 4000 Byte, the datagram size is no longer relevant. As at a such point the value of  $\tau$  is low, we can take the corresponding PCR as being the searched value (Table 5).

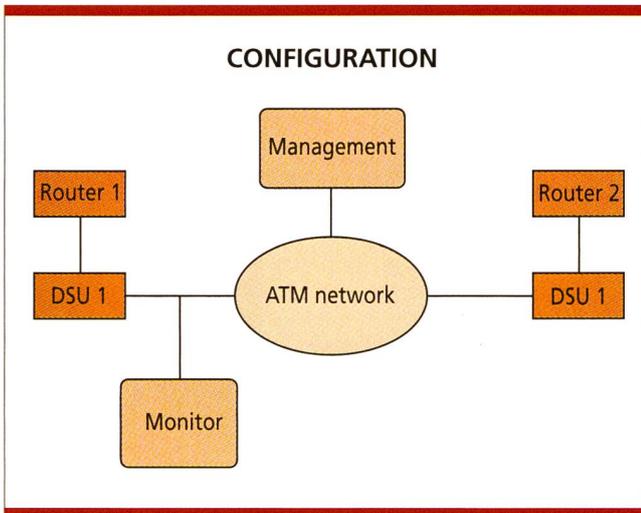


Fig. 7. Configuration approach 4.

**Approach 4: Measurement of the minimum possible bandwidth for a traffic between routers (ping)**

Given a fixed CDV of 1325  $\mu s$ , we start pinging from router 1 to router 2 (Fig. 7). The interval between two ping packets is determined by the answer time, i.e., as soon as the 'pong' has arrived from router 2, router 1 sends the next ping.

During this exercise the peak cell rate is decreased by steps of 500 cps in the ATM network, until a cell-discard event is reported on the management console. Simultaneously, the router reports an error, as no answer is received (Table 6).

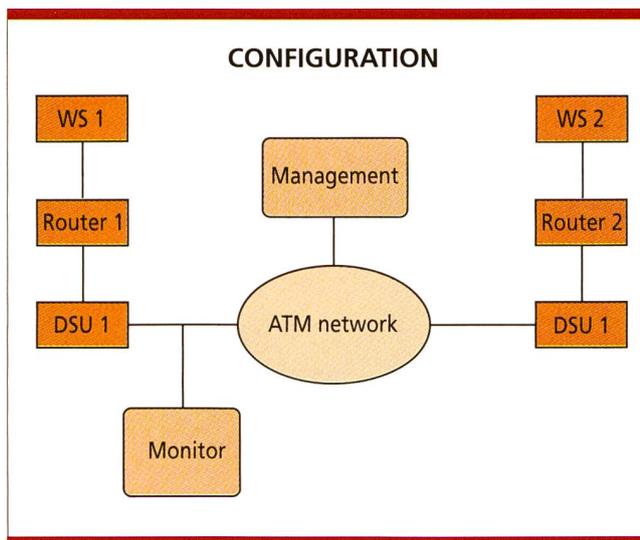


Fig. 8. Configuration approach 5.

**Approach 5: Measurement of the minimum possible bandwidth for a traffic end to end, i.e. between workstations (file transfer application)**

The same scenario is executed as in approach 4 (Fig. 8). This time the application is a FTP with two files, one of

**Approach 3: Study of the couple  $T$  (peak emission interval) and  $\tau$  (cell delay variation tolerance) on a recorded traffic**

The network is configured as in Figure 5. The application used to generate the traffic is the 'ping' between rout-

ers. The ping packet size is a parameter of the router ping command and is defined in turn as 1500, 4000 and 9180 Byte.

The PCR is observed over a long period with the results in Table 3. The monitor then records each cell of the connection and its arrival time.

| DSU clock | approach 1    | approach 2 | approach 3 | approach 4 | approach 5 |
|-----------|---------------|------------|------------|------------|------------|
| 2.5 MHz   | <b>7 887</b>  | 7 180      | 7 000      | 7 000      | 7 500      |
| 8 MHz     | <b>25 237</b> | 22 939     | 23 000     | 20 500     | 22 500     |
| 16 MHz    | <b>50 474</b> | 38 369     | 45 500     | 30 500     | 25 500     |

Table 1. Peak cell rate [cps] calculated for different DSU clock rate settings [MHz].

| DSU clock | approach 1 | approach 2    | approach 3 | approach 4 | approach 5 |
|-----------|------------|---------------|------------|------------|------------|
| 2.5 MHz   | 7 887      | <b>7 180</b>  | 7 000      | 7 000      | 7 500      |
| 8 MHz     | 25 237     | <b>22 939</b> | 23 000     | 20 500     | 22 500     |
| 16 MHz    | 50 474     | <b>38 369</b> | 45 500     | 30 500     | 25 500     |

Table 2. Peak cell rate [cps] calculated for different DSU clock rate settings [MHz].

| DSU clock rate | PCR observed for a ping size of 1500 Byte | PCR observed for a ping size of 4000 Byte | PCR observed for a ping size of 9180 Byte |
|----------------|---|---|---|
| 2.5 MHz        | 1 440                                     | 1 475                                     | 2 143                                     |
| 8 MHz          | 3 132                                     | 3 407                                     | 5 139                                     |
| 16 MHz         | 4 287                                     | 4 876                                     | 6 848                                     |

Table 3. Peak cell rate [cps] observed, when changing the DSU clock rate and the ping size.

| PCR [cps]    | $\tau$ [usecs] for datagram size |            |            | $\Delta\tau$ [%] for datagram |               |           |
|--------------|----------------------------------|------------|------------|-------------------------------|---------------|-----------|
|              | 1500 Byte                        | 4000 Byte  | 9180 Byte  | 1500 Byte                     | 4000 Byte     | 9180 Byte |
| 6 000        | 1 526                            | 2 765      | 6 112      | 25.0 %                        | 45.2 %        | 100.0 %   |
| 6 500        | 1 038                            | 1 599      | 3 343      | 31.1 %                        | 47.8 %        | 100.0 %   |
| <b>7 000</b> | <b>621</b>                       | <b>599</b> | <b>969</b> | <b>64.1 %</b>                 | <b>61.8 %</b> | 100.0 %   |
| 7 500        | 452                              | 367        | 421        | 107.4 %                       | 87.2 %        | 100.0 %   |
| 8 000        | 393                              | 335        | 362        | 108.6 %                       | 92.5 %        | 100.0 %   |
| 8 500        | 342                              | 313        | 318        | 107.5 %                       | 98.4 %        | 100.0 %   |
| 9 000        | 296                              | 294        | 294        | 100.9 %                       | 100.0 %       | 100.0 %   |
| 9 500        | 276                              | 276        | 276        | 100.0 %                       | 100.0 %       | 100.0 %   |

Table 4.  $\tau$  values for different ping datagram sizes, ratio between the  $\tau$  value, taking the  $\tau$  for datagram 9180 as 100 %.

| DSU clock | approach 1 | approach 2 | approach 3    | approach 4 | approach 5 |
|-----------|------------|------------|---------------|------------|------------|
| 2.5 MHz   | 7 887      | 7 180      | <b>7 000</b>  | 7 000      | 7 500      |
| 8 MHz     | 25 237     | 22 939     | <b>23 000</b> | 20 500     | 22 500     |
| 16 MHz    | 50 474     | 38 369     | <b>45 500</b> | 30 500     | 25 500     |

Table 5. Peak cell rate [cps] found for different DSU clock rate settings [MHz].

| DSU clock | approach 1 | approach 2 | approach 3 | approach 4    | approach 5 |
|-----------|------------|------------|------------|---------------|------------|
| 2.5 MHz   | 7 887      | 7 180      | 7 000      | <b>7 000</b>  | 7 500      |
| 8 MHz     | 25 237     | 22 939     | 23 000     | <b>20 500</b> | 22 500     |
| 16 MHz    | 50 474     | 38 369     | 45 500     | <b>30 500</b> | 25 500     |

Table 6. Minimum possible peak cell rate [cps] for different DSU clock rates [MHz] found during the ping application.

| DSU clock | approach 1 | approach 2 | approach 3 | approach 4 | approach 5    |
|-----------|------------|------------|------------|------------|---------------|
| 2.5 MHz   | 7 887      | 7 180      | 7 000      | 7 000      | <b>7 500</b>  |
| 8 MHz     | 25 237     | 22 939     | 23 000     | 20 500     | <b>22 500</b> |
| 16 MHz    | 50 474     | 38 369     | 45 500     | 30 500     | <b>25 500</b> |

Table 7. Minimum possible peak cell rate [cps] for different DSU clock rates [MHz] found during the file transfer application.

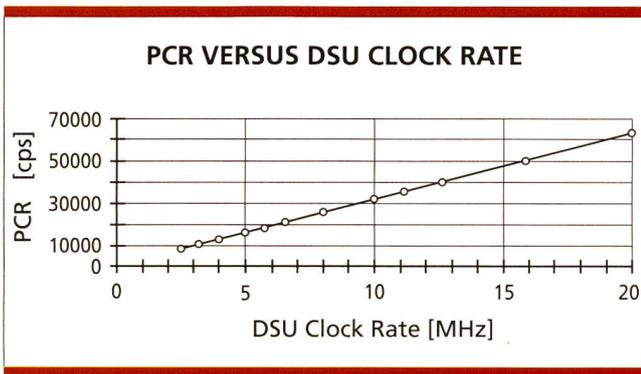


Fig. 9. Peak cell rate versus DSU clock rate.

1 MByte and one of 10 MByte. The bandwidth is decreased in the ATM network until a cell-discard event occurs. Please note that from the application point of view the cell-discard process can only be seen by comparing the mean transfer time given by FTP (Table 7).

### Conclusion

Figure 9 gives the suggested bandwidth to be set up in the ATM Pilot network for the different values of the DSU clock rate and for a CDV of

1325  $\mu$  s. We took the maximum value found and rounded it up to 100 cps. The maximum is in fact the value calculated for the theoretical approach. The other measurements have confirmed the rightness of this approximation.

Swiss Telecom PTT is currently using these values to define our national and international connections. They apply not only for DSU-to-DSU connections, but also for DSU-to-CLS (connection less server) traffic. However, some questions remain:

- All the measurements have been made with a predefined CDV value.

How shall we adapt this CDV parameter to make the best usage of the network?

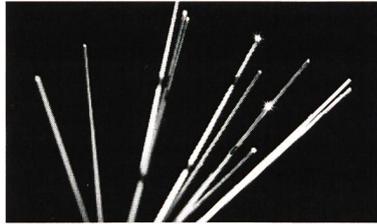
- What is happening to the shape of the traffic after crossing two, three, four or more cross-connects?
- Another type of DSU may produce another traffic shape. Is it possible to deduce a universal law governing the LAN interconnection?

The work of traffic characterization continues within Swiss Telecom PTT and in the PWG (Performance Working Group) of the EAP (European ATM Pilot), where we are active.



**Benoit Piller** joined the Broadband Network Group of the Research and Development Department of Swiss Telecom PTT in 1993. He has been involved in the core network testing and interoperability campaigns of the European ATM Pilot network. He is currently the Swiss Telecom PTT representative in the Performance Working Group of the European ATM Pilot.

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