This material is from the specification (Traffic Management Specification, Version 4.1, AF-TM-0121.000) of the ATM Forum

4.4.2 Generic Cell Rate Algorithm (GCRA)

The GCRA is used to define conformance with respect to the traffic contract. For each cell arrival, the GCRA determines whether the cell conforms to the traffic contract of the connection. The UPC function may implement the GCRA, or one or more equivalent algorithms to enforce conformance. Although traffic conformance is defined in terms of the GCRA, the network is not required to use this algorithm (or the same parameter values) for the UPC. Rather, the network may use any UPC as long as the operation of the UPC supports the QoS objectives of a compliant connection.

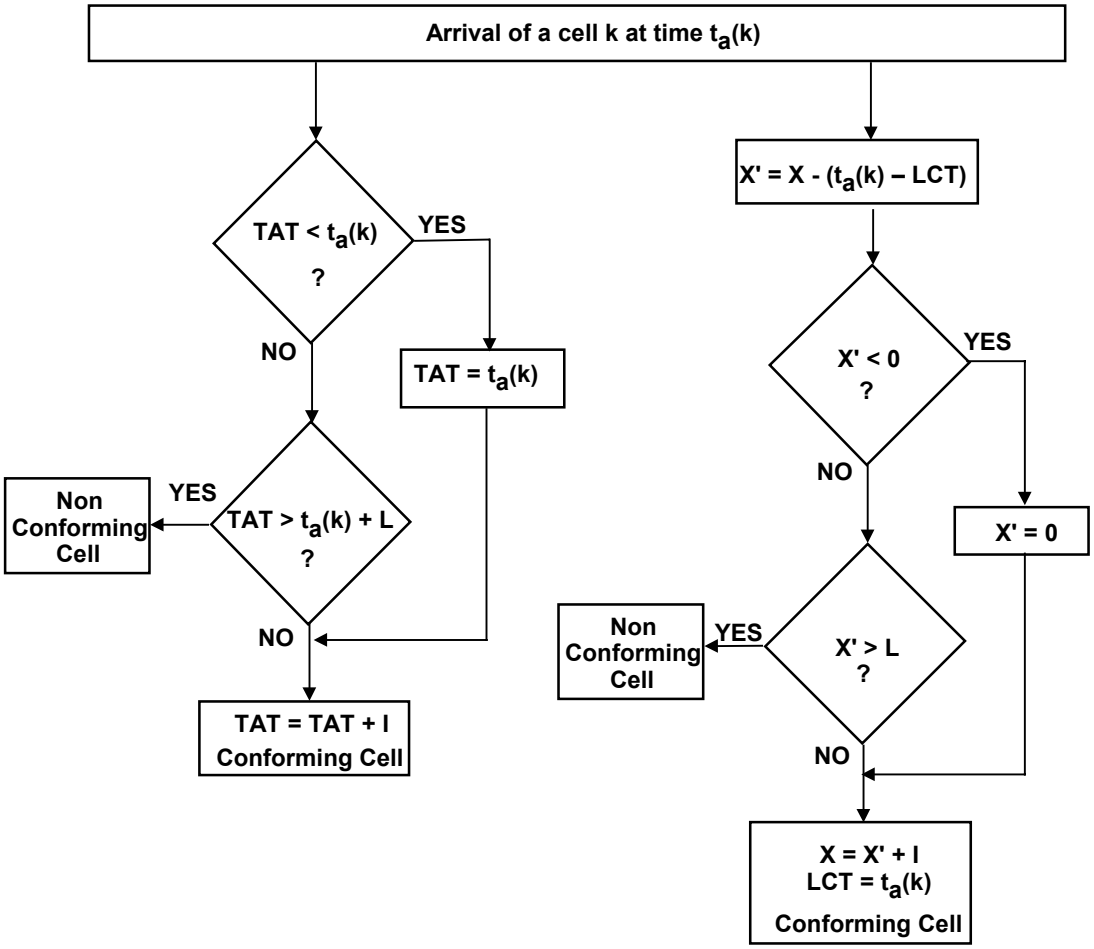
The GCRA is a virtual scheduling algorithm or a continuous-state Leaky Bucket Algorithm as defined by the flowchart in Figure 4-1. The GCRA is used to define, in an operational manner, the relationship between PCR and the CDVT, and the relationship between SCR and the Burst Tolerance (BT). The BT can be derived from PCR, SCR, and MBS according to Annex B.4. In addition, the GCRA is used to specify the conformance, at the public or private UNI, of the declared values of the above two tolerances, as well as declared values of the traffic parameters PCR and SCR and MBS. See Section 4.4.3.2.

The GCRA is defined with two parameters: the Increment (I) and the Limit (L). The notation "GCRA(I, L)" means the Generic Cell Rate Algorithm with the value of the increment parameter set equal to I and the value of the limit parameter set equal to L. Note: I and L are not restricted to integer values. The GCRA is formally defined in Figure 4-1. Figure 4-1 is a generic version of Figure 1 in Annex 1 of I.371. The two algorithms in Figure 4-1 are equivalent in the sense that for any sequence of cell arrival times, $\{t_a(k), k >= 1\}$, the two algorithms determine the same cells to be conforming and thus the same cells to be non-conforming. The two algorithms are easily compared by noticing that at each arrival epoch, $t_a(k)$, and after the algorithms have been executed, TAT = X + LCT, as in Figure 4-1.

Multiple instances of the GCRA with possibly different I and L parameters may be applied to multiple flows (CLP=0 and CLP=0+1) of the same connection, or to the same flow. A cell is then conforming only if it conforms to all instances of the GCRA against which cells with its CLP state are tested. For example, if one instance of the GCRA tests the CLP=0 flow and one instance tests the CLP=0+1 flow, then a CLP=0 cell is conforming only if it conforms to both instances of the GCRA. In this same configuration, a CLP=1 cell is conforming only if it conforms to the instance of the GCRA that tests the CLP=0+1 flow. If tagging is used, a tagged cell is conforming only if it conforms as a CLP=1 cell. The state of a particular instance of the GCRA is updated only by the cells that conform as part of a flow tested by that instance of the GCRA. For example, a conforming tagged cell will not update the state of an instance of the GCRA that tests the CLP=0 flow, since the tagged cell conforms as a CLP=1 cell. Detailed flow-charts illustrating the interaction between multiple instances of the GCRA algorithm are given in ITU-T Recommendation I.371.

4.4.3 Peak Cell Rate Conformance

The Peak Cell Rate (PCR) traffic parameter specifies an upper bound on the rate at which traffic can be submitted on an ATM connection. Enforcement of this bound by the UPC allows the network to allocate sufficient resources to ensure that the network performance objectives (e.g., for Cell Loss Ratio) can be achieved.



VIRTUAL SCHEDULING ALGORITHM

TAT	Theoretical Arrival Time
$t_a(k)$	Time of arrival of a cell
I	Increment
L	Limit

At the time of arrival t_a of the first cell of the connection, TAT = $t_a(1)$

CONTINUOUS-STATE LEAKY BUCKET ALGORITHM

X	Value of the Leaky Bucket counter
X'	auxiliary variable
LCT	Last Conformance Time

At the time of arrival t_a of the first cell of the connection, X = 0 and LCT = $t_a(k)$

Figure 4-1: Equivalent versions of the Generic Cell Rate Algorithm

In the signaling message, the PCR is coded in cells per second (see UNI Signaling 4.0). The defined coding for the PCR in the signaling message does not imply that any UPC mechanism has to support the same linear granularity for the PCR across the complete defined cell rate range.

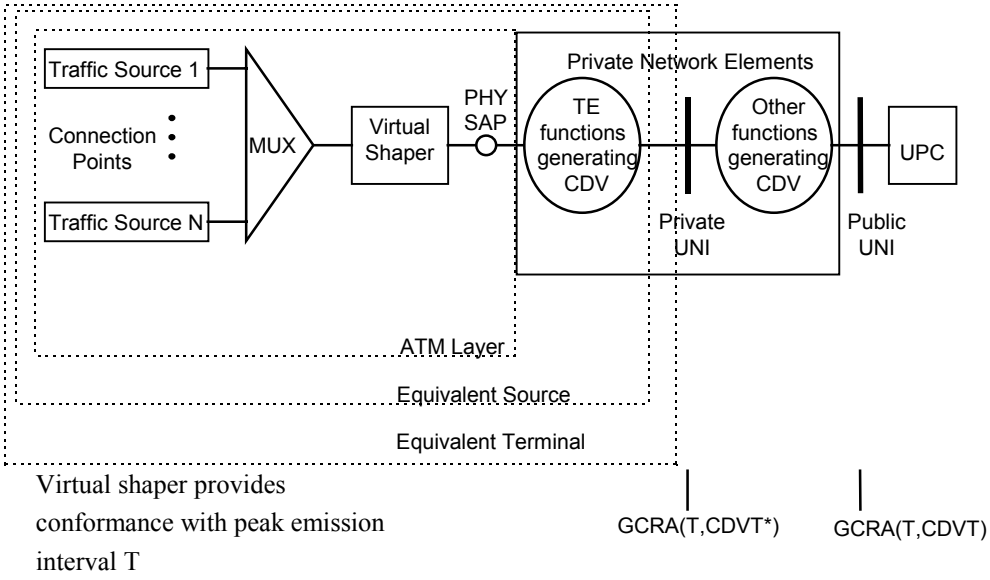


Figure 4-2: PCR Reference Model

4.4.3.1 PCR Reference Model

The equivalent-terminal configuration is given in Figure 4-2. It provides an abstract framework for describing the UPC at the public UNI. A similar model applies when UPC is implemented at the private UNI. Traffic sources, the multiplexer and the shaper define the equivalent-terminal. This is an abstraction that does not preclude any particular implementation of the end-system. This figure shows one or more private network elements that contain ATM layer switching and/or multiplexing, and therefore contribute to CDV, as observed at the public UNI.

All traffic sources (AALs, etc.) offering cells to a connection are put together in the equivalent-terminal. Each source generates requests to send ATM cells at its own rate. All requests are multiplexed in a Multiplexer (MUX in Figure 4-2) before entering the virtual shaper.

The virtual shaper is intended to reflect some smoothness in the cell flow offered to the connection: at the PHY_SAP, the minimal inter-arrival time between two consecutive requests is greater than or equal to T, which is called the peak emission interval of the connection. The output of the virtual shaper at the PHY_SAP of the equivalent-terminal conforms to GCRA(T, 0). This conformity cannot be required at the Private or Public UNIs since CDV is allowed in the private network elements as well as in the end-system. The output of the virtual shaper is affected by functions in the equivalent-terminal that cause CDV characterized by $CDVT^*$. The value of $CDVT^*$ is chosen such that the output cell flow conforms to GCRA(T, $CDVT^*$).

The output of the equivalent-terminal is affected by functions in other CPE that may modify the CDV at the Public UNI characterized by CDVT. The value of CDVT is chosen such that the output cell flow conforms to GCRA(T, CDVT).

The value of the peak emission interval T is user specific to allow for intelligent multiplexing within the end-system. For instance, AALs producing sporadic traffic may be synchronized to share the same transmission capacity. In other cases, T may be set to account for the combined activity of all traffic sources, e.g., the PCR of a VPC may be the sum of the PCRs of the VCCs contained in the VPC.

The PCR traffic parameter is defined at the PHY_SAP within an equivalent-terminal. The CDVT specified at the private UNI ($CDVT^*$) (i.e., that directly connects an end-system to a private network) accounts for the cell clumping introduced by the end-system. The CDVT specified at the public UNI (CDVT) (i.e., that connects an end-system to a public network through a private ATM network via a private UNI) accounts for the cell clumping introduced by the end-system and the private ATM network.

4.4.3.2 PCR Parameter Definition

The following definition applies to connections supporting CBR, rt-VBR, nrt-VBR, ABR, UBR, and GFR services.

The PCR definition for a connection is as follows:

- **Location:** At the PHY_SAP in an equivalent-terminal representing the connection (this is only a reference configuration; see Figure 4-2)
- **Basic Event**: Request to send an ATM_PDU in the equivalent-terminal.

- **Definition:** The PCR of the ATM connection is the inverse of the minimum inter-arrival time T between two basic events above. T is called the peak emission interval of the connection.

An interpretation of the definition of PCR and the equivalent terminal is given in Annex B.2.

4.4.3.3 CDVT

As shown in Figure 4-2, the CDVT is defined in relation to the PCR according to the GCRA. In particular, the CDVT at the public UNI, is defined in relation to the PCR according to the algorithm GCRA(T, CDVT), where T is the inverse of PCR. Likewise, the CDVT at the private UNI, CDVT*, is defined in relation to the PCR according to the algorithm GCRA(T, CDVT*).

4.4.4 Sustainable Cell Rate and Burst Tolerance

The SCR is an upper bound on the average rate of the conforming cells of an ATM connection, over time scales that are long relative to those for which the PCR is defined. Enforcement of this bound by the UPC could allow the network to allocate sufficient resources, but less than those based on the PCR, and still ensure that the performance objectives (e.g., for Cell Loss Ratio) can be achieved.

Note: ITU-T Recommendation I.371 refers to Burst Tolerance as Intrinsic Burst Tolerance (IBT).

4.4.4.1 SCR and BT Reference Model

The SCR Reference Model is defined with reference to Figure 4-3. The SCR and BT traffic parameters are defined at the PHY_SAP within an equivalent-terminal.

4.4.4.2 SCR and BT Definitions

The following definition applies to connections supporting rt-VBR and nrt-VBR services. The SCR and BT parameters for a connection are defined according to the GCRA (Section 4.4.2) as follows:

- **Location:** At the PHY_SAP in an equivalent-terminal representing the connection (this is only a reference configuration; see Figure 4-3).
- **Basic Event:** Request to send an ATM_PDU in the equivalent-terminal.
- **Definition:** The SCR, and the BT denoted as of the ATM connection are defined by the GCRA(1/SCR, BT) based on the arrivals of the basic event defined above. The increment parameter of the GCRA is 1/SCR and BT is the limit parameter of the GCRA.

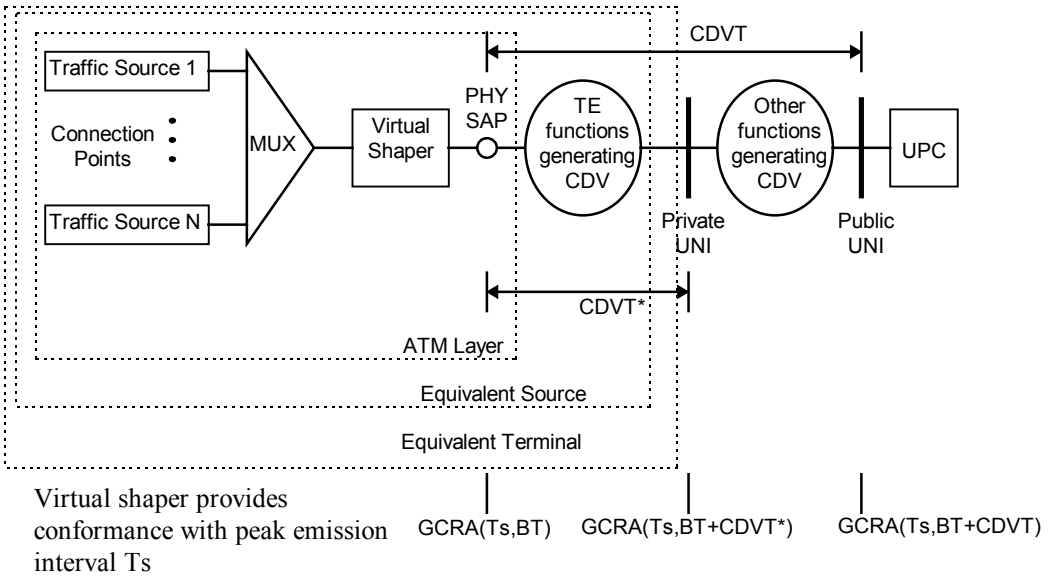


Figure 4-3: SCR and BT Reference Model

In the signaling message, the SCR is coded as cells per second. The granularity supported by the signaling message is 1 cell/s. The defined coding for the SCR in the signaling message does not imply that any UPC mechanism has to support the same linear granularity for the SCR across the complete defined cell rate range. An interpretation of the definition of SCR and BT in conjunction with PCR is given in Annex B.4.

4.4.4.3 CDVT

As shown in Figure 4-3, the CDVT is defined in relation to the SCR according to the GCRA. In particular, the CDVT at the public UNI, is defined in relation to the SCR according to the algorithm GCRA(T_S, BT+CDVT), where T_S is the inverse of SCR. Likewise, the CDVT* at the private UNI, is defined in relation to the SCR according to the algorithm GCRA(T_S, BT+CDVT*).

4.5 Traffic Contract and Conformance Definitions

The conformance of cells of a connection at an interface is defined in relation to the conformance algorithm and corresponding parameters specified in the connection traffic descriptor. This conformance definition is specified in the traffic contract. The set of conformance definitions that is supported at the public UNI is network specific. Future service categories may require the definition of new traffic contract parameters.

The ITU-T provides a definition of the granularity of PCR, SCR, CDVT, and BT used for defining conformance of a CBR or VBR connection, see ITU-T Recommendation I.371.

For network operations, there are two models for the CLP=1 cell flow:

- **CLP-transparent**: The network generally disregards the CLP bit. The CLR objective applies only to the aggregate CLP=0+1 cell flow, for which the CLP=1 cells experience the same CLR as the CLP=0 cells. The tagging option does not apply to this model (see Section 5.3.6).
- **CLP-significant**: The CLR objective applies only to the CLP=0 cell flow. The CLR for the CLP=1 flow is unspecified, as is the CLR for the aggregate flow (CLP=0+1). Network tagging applies as an option. The network may make a best-effort attempt to transmit the CLP=1 flow. In such a case, the network is likely to employ selective discard (but this will not count against the CLR objective of the connection).

For the conformance definitions listed below, the CLP-transparent model is used for CBR.1 and VBR.1, and the CLP-significant model is used for VBR.2, VBR.3, GFR.1 and GFR.2.

4.5.1 Traffic Contract and Conformance Definition for CBR Service

Conformance for a CBR connection is characterized by PCR and the corresponding CDVT for the CLP=0+1 traffic flow.

(R) PCR for CLP=0+1 is a mandatory traffic parameter in any CBR source traffic descriptor.

(R) For CBR SVCs, the PCR for CLP=0+1 shall be explicitly specified by the source for each direction in the initial connection establishment message.

(R) The CDVT is a mandatory parameter in any CBR connection traffic descriptor.

(R) The CDVT shall be either explicitly specified at subscription time or implicitly specified for any CBR connection.

(R) For SVCs, the signaling message shall be capable of conveying information that identifies at least the following set of conformance definitions. For PVCs, the conformance definition shall be explicitly identified at subscription time.

4.5.1.1 CBR.1: Conformance Definition for PCR (CLP=0+1)

The following is a conformance definition for a source traffic descriptor that specifies PCR for the CLP=0+1 cell stream:

1. One GCRA(T_{0+1}, CDVT) defining the CDVT in relation to the PCR of the CLP=0+1 cell stream. T_{0+1} is the inverse of the PCR specified for the CLP=0+1 cell flow.
2. A cell that is conforming to the GCRA in (1) is said to be conforming to the connection traffic descriptor.

The tagging option is not applicable to this conformance definition since no separate rate is specified for CLP=0. The CLR objective applies to the aggregate CLP=0+1 cell stream.

4.5.2 Traffic Contract and Conformance Definition for rt-VBR and nrt-VBR

Conformance for a rt-VBR or nrt-VBR connection is characterized by an SCR parameter and corresponding MBS parameter for one or more traffic flows, in addition to a PCR parameter and corresponding CDVT for at least the CLP=0+1 flow. Real-time VBR and nrt-VBR are typically distinguished by their QoS parameters, but also by the magnitude(s) of the MBSs supported. Larger MBSs are more typical for nrt-VBR connections. The relationship between BT and MBS is given in Annex B.4.

(R) PCR for CLP=0+1 is a mandatory traffic parameter in any source traffic descriptor for a rt-VBR or nrt-VBR connection.

(R) For rt-VBR or nrt-VBR SVCs, the PCR for CLP=0+1 must be explicitly specified for each direction in the initial establishment message.

(R) CDVT is a mandatory parameter in any connection traffic descriptor for a rt-VBR or nrt-VBR connection.

(R) CDVT shall be either explicitly specified at subscription time or implicitly specified for any rt-VBR or nrt-VBR connection.

(R) For SVCs, the signaling message shall be capable of conveying information that identifies at least the following set of conformance definitions. For permanent connections the conformance definition shall be explicitly identified at subscription time.

4.5.2.1 VBR.1: Conformance Definition for PCR (CLP=0+1) and SCR (CLP=0+1)

The following is a conformance definition for a source traffic descriptor that specifies PCR for the CLP=0+1 cell stream and SCR for the CLP=0+1 cell stream:

1. One GCRA(T_{0+1}, CDVT) defining the CDVT in relation to the PCR of the CLP=0+1 cell stream. T_{0+1} is the inverse of PCR (CLP=0+1).
2. One GCRA(T_{s0+1}, BT_{0+1}+CDVT) defining the sum of the CDVT and the BT in relation to the SCR of the CLP=0+1 cell stream. T_{s0+1} is the inverse of SCR (CLP=0+1).
3. A cell that is conforming to both GCRAs (1) and (2) above is said to be conforming to the connection traffic descriptor.

The tagging option is not applicable to this conformance definition. The CLR objective applies to the aggregate CLP=0+1 cell stream.

4.5.2.2 VBR.2: Conformance Definition for PCR (CLP=0+1) and SCR (CLP=0)

The following is a conformance definition for a source traffic descriptor that specifies PCR for the CLP=0+1 cell stream and SCR for the CLP=0 cell stream:

1. One GCRA(T_{0+1}, CDVT) defining the CDVT in relation to the PCR of the CLP=0+1 cell stream. T_{0+1} is the inverse of PCR (CLP=0+1).
2. One GCRA(T_{s0}, BT_0+CDVT) defining the sum of the CDVT and the BT in relation to the SCR of the CLP=0 cell stream. T_{s0} is the inverse of SCR (CLP=0).
3. A CLP=0 cell that is conforming to both GCRAs (1) and (2) above is said to be conforming to the connection traffic descriptor. A CLP=1 cell that is conforming to GCRA (1) above is said to be conforming to the connection traffic descriptor.

This conformance definition allows a connection to send CLP=1 cells at a PCR equal to the specified PCR of the CLP=0+1 cell stream. The CLR objective applies to the CLP=0 cell stream. The CLR of the CLP=1 cell-stream and the aggregate stream is undefined.

4.5.2.3 VBR.3: Conformance Definition for PCR (CLP=0+1) and SCR (CLP=0)

The following is a conformance definition for a source traffic descriptor that specifies PCR for the CLP=0+1 cell stream and SCR for the CLP=0 cell stream:

1. One GCRA(T_{0+1}, CDVT) defining the CDVT in relation to the PCR of the CLP=0+1 cell stream. T_{0+1} is the inverse of PCR (CLP=0+1).
2. One GCRA(T_{s0}, BT_0+CDVT) defining the sum of the CDVT and the BT in relation to the SCR of the CLP=0 cell stream. T_{s0} is the inverse of SCR (CLP=0).
3. A CLP=0 cell that is conforming to both GCRAs (1) and (2) above is said to be conforming to the connection traffic descriptor. A CLP=1 cell that is conforming to GCRA (1) above is said to be conforming to the connection traffic descriptor.
4. If the end-system requests tagging, and if tagging is supported by the network, a CLP=0 cell that is not conforming to GCRA (2) above, but is conforming to GCRA (1) above, will have its CLP bit changed to 1 and is said to be conforming to the connection traffic descriptor.

This conformance definition allows a connection to send CLP=1 cells at a PCR equal to the specified PCR of the CLP=0+1 cell stream. The CLR objective applies to the CLP=0 cell stream. The CLR of the CLP=1 cell-stream and the aggregate stream is undefined.

4.5.3 Traffic Contract and Conformance Definition for UBR Service

Conformance for a UBR connection is characterized by a single PCR and corresponding CDVT for the CLP=0+1 flow. The use of PCR for CAC, and enforcement of PCR by UPC, is network specific. However, if the user requests a non-zero minimum acceptable PCR that cannot be supported by the network, then the network may reject the call.

(R) PCR for CLP=0+1 is a mandatory traffic parameter in any source traffic descriptor of a UBR connection.

(R) The CDVT is a mandatory parameter in any connection traffic descriptor for a UBR connection.

(R) The CDVT shall be either explicitly specified at subscription time or implicitly specified for a UBR connection.

(R) For UBR SVCs, the PCR for CLP=0+1 shall be explicitly specified for each direction in the initial establishment message.

It is desirable that the source end-system conforms to PCR, but the enforcement of this is network specific.

4.5.3.1 UBR.1: Conformance definition for PCR (CLP=0+1), Tagging not applicable

The tagging option does not apply. The network shall not overwrite the CLP bit.

4.5.3.2 UBR.2: Conformance definition for PCR (CLP=0+1), Tagging applicable

The tagging option applies. The network may overwrite the CLP bit to 1 for any cell of that connection. However, such action does not necessarily imply a condition of non-conformance, as would be the case for other service categories.

4.5.6 Summary of Conformance Definitions

Table 4-1 summarizes the conformance definitions discussed in this section for the CBR, VBR, ABR, GFR and UBR service categories.

Conformance Definition	PCR flow	SCR flow	Tagging option active	MCR	CLR on
CBR.1	0 + 1	ns_1	n/a_2	ns	0 + 1
VBR.1	0 + 1	0 + 1	n/a	ns	0 + 1
VBR.2	0 + 1	0	No	ns	0
VBR.3	0 + 1	0	Yes	ns	0
UBR.1	0 + 1	ns	No	ns	U_3
UBR.2	0 + 1	ns	Yes_4	ns	U

Table 4-1: Summary of conformance definitions

Notes for Table 4-1:

1. ns means not specified.
2. n/a means that tagging is not applicable.
3. U means that CLR is unspecified (for both CLP=0 & CLP=1).
4. When the tagging option is used for a UBR connection the network may overwrite the CLP bit to 1 for any cell of that connection. However, such action does not necessarily imply a condition of non-conformance, as would be the case for other service categories.
5. Tagging is applicable to all cells of a frame that is deemed ineligible for the service guarantee. Tagging has to be applied uniformly in all cells of a frame.
6. CLR is low for sources that adjust cell flow in response to control information. Whether a quantitative value for CLR is specified is network specific.
7. CLR is low for frames that are eligible for the service guarantee. Whether a quantitative value for CLR is specified is network specific.