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TITLE: The Traffic Conformance in ATM Network
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Summary
An application negotiates a traffic contract with the network for each virtual connection. The traffic contract is an agreement on the behavior of the traffic and the level of service that is required for the connection. One key element of the traffic contract is the service category[1] . The traffic contract is defined for a connection, the network applies a connection admission algorithm to evaluate whether the connection can be admitted and achieve the expected QoS but without jeopardizing the QoS of previous established connections.If the connection is accepted, then the cells can start to flow in the network. In order to guarantee that QoS is maintained for both new connection and existing ones, the network has to ensure that the connection's traffic follows the traffic contract. Therefore the network can apply to the traffic flow conformance monitoring functions to ensure that a misbehaving user cannot affect the QoS of other users. This paper focuse on analyzing traffic conformance in ATM-Network for the service categories: Constant Bit Rate (CBR) and Variable Bit Rate (VBR)

1. Introduction

The inherent conflict created by the need to optimize bandwidth while ensuring different QoS can be resolved by using a combination of traffic control or traffic management techniques. The ATM technology, with its sophisticated traffic management capabilities, is the key to meeting these conflicting objectives. Furthermore, ATM can handle diverse access speeds and adapt easily to non-native ATM traffic while consolidating traffic from various protocols over a single network infrastructure.
ATM traffic management (TM) can be divided into layers of functions and procedures. Figure 1 depicts the relationship of the ATM layer traffic management components. A service category defines the expected quality of service (QoS) class and also specifies the expected behavior of the traffic generated by the application (traffic descriptors).
The traffic that successfully passes through the conformance monitoring function enters the network and is multiplexed at different points. In order to achieve statistical multiplexing gains, the traffic may be queued or buffered before being transmitted on intermediate links. Although connection admission is performed at connection setup, congestion in network elements (overflowing of the buffers) can still occur. Congestion is

caused by statistical overlap of traffic bursts at a contention point. Congestion control deals with the handling of traffic arriving at a contention point to ensure that cells are discarded in a fair manner and that QoS is guaranteed.

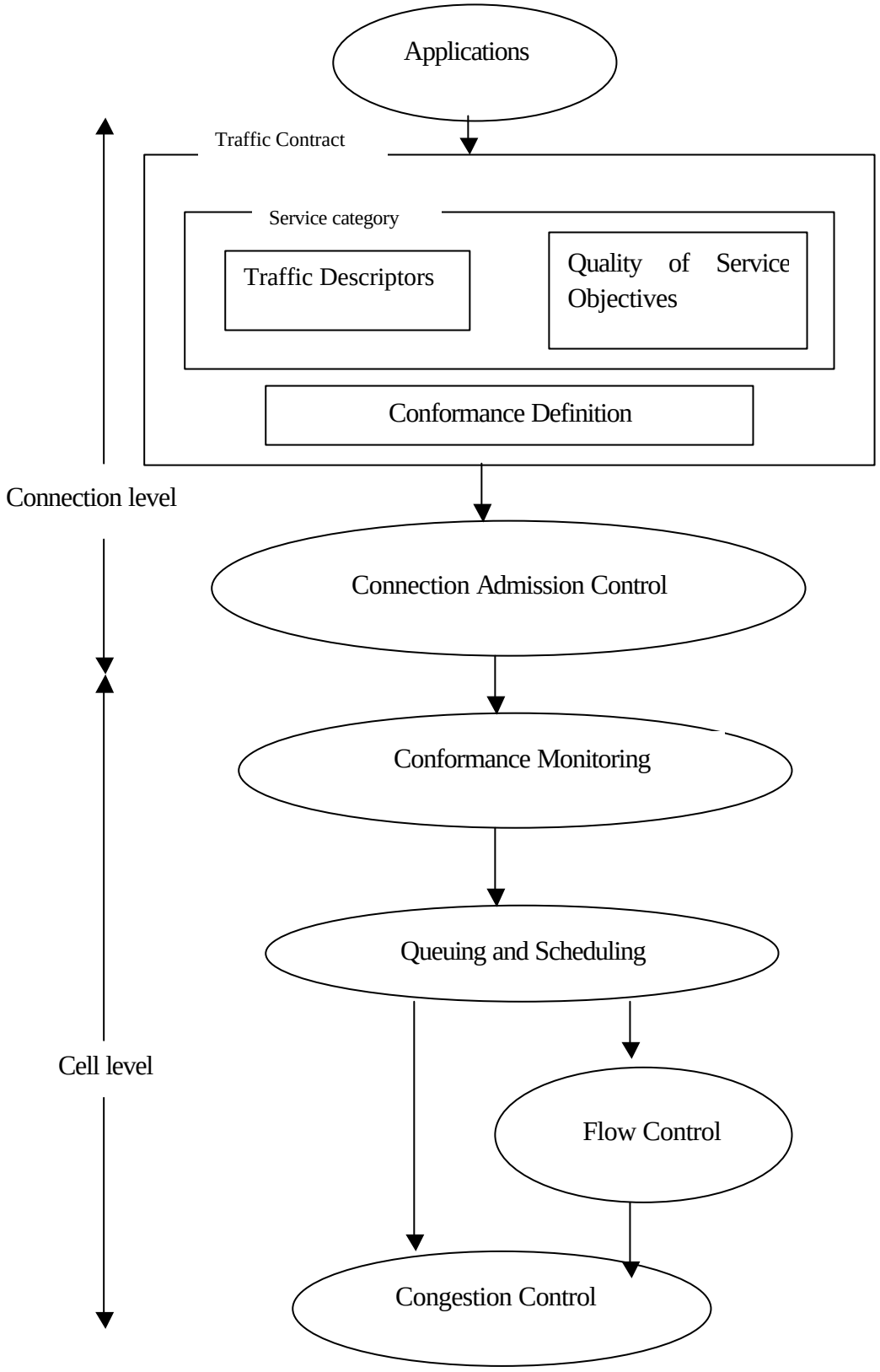

Figure 1: Relationship of traffic management functions

2. The service categories and its conformance definitions:

2.1. The service categories

ATM allows implementation of such a consolidated network, since it can simultaneously support the quality of service required by any existing applications as well as any foreseeable new applications- through the selection of an appropriate service category.

The service categories are:

- Constant bit rate (CBR) service,
- Variable bit rate (VBR) service,
- Available bit rate (ABR) service,
- Guaranteed frame rate (GFR) service,
- Unspecified bit rate (UBR) service,

For CBR and VBR services, bandwidth is allocated by the connection admission control (CAC) for the duration of the connection. The ABR, GFR, and UBR services target the dynamically available bandwidth for use. These services are referred to as bandwidth-on-demand services. The goal of bandwidth-on-demand services is to acquire as fast as possible a fair share of the bandwidth that is dynamically available in the network.

Six QoS parameters are used to measure the performance of the network for a given connection. Three of these may be negotiated between the end-systems and the networks as part of the traffic contract [1]:

- cell loss ratio (CLR)
- maximum cell transfer delay (Max-CTD)
- peak-to-peak cell delay variation (P2P-CDV)

Three other QoS parameters are not negotiable as part of the traffic contract:

- cell error ratio (CER)
- severely errored cell block ratio (SECBR)
- cell misinsertion rate (CMR)

Figure 2 depicts the impact of queuing on the traffic characteristics. In this example, VC1 is multiplexed with six other VCs with different contracted PCR. In this example the input and output links are all of the same speed.

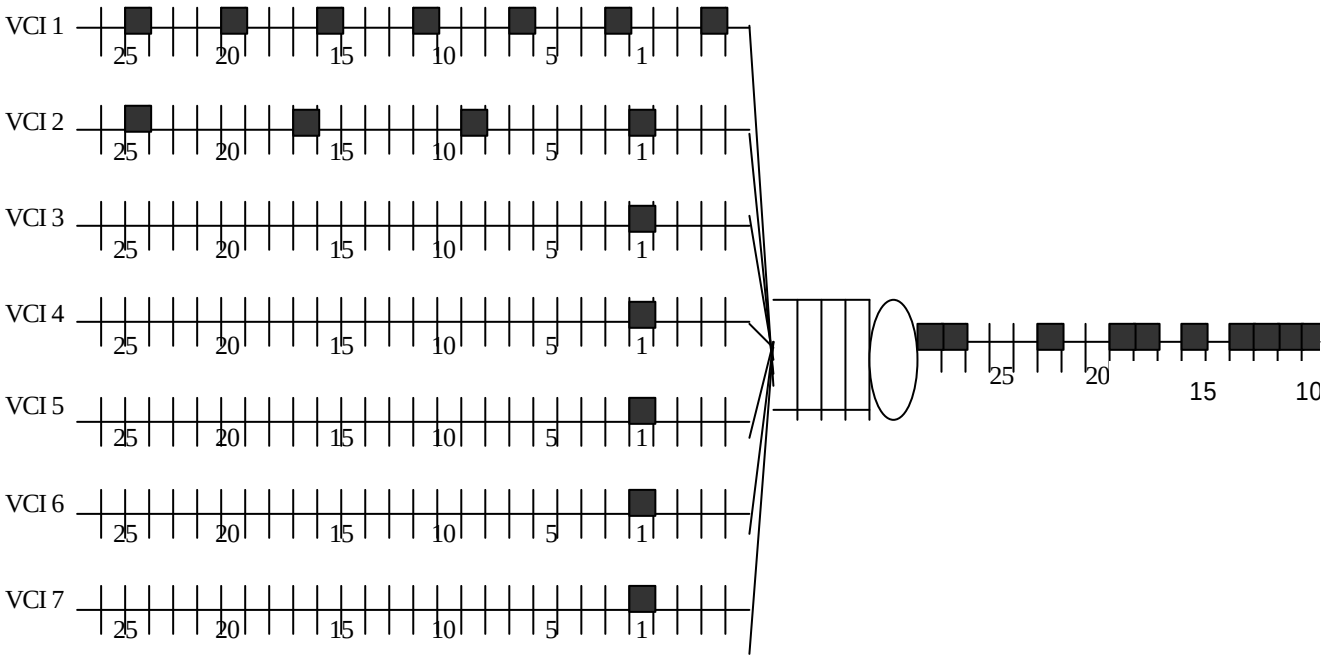

Figure 2: CDV illustration.

2.2. CBR Test Source Measurement of CDV :

A Continuous Bit-Rate (CBR) source emits a cell once every T seconds (note this implies that T is a multiple of the cell slot time in the TDM transmission convergence sublayer). This cell stream, perfectly spaced, is transmitted across an ATM network that introduces variations in delay that we wish to measure.The receiver knows the spacing interval T, and can compute the interarrival times of successive cells and subtract the time T to result in a 1-point CDV estimate. Positive values of the 1-point CDV estimate correspond to cell clumping, while negative values of the 1-point CDV estimate correspond to gaps , or dispersion,in the cell stream.. As shown in Figure 3 cell clumping occurs for cells that are closer together, while dispersion occurs for cells spaced too far apart . This is important for determining the likelihood of overrun and underrun for CBR services.

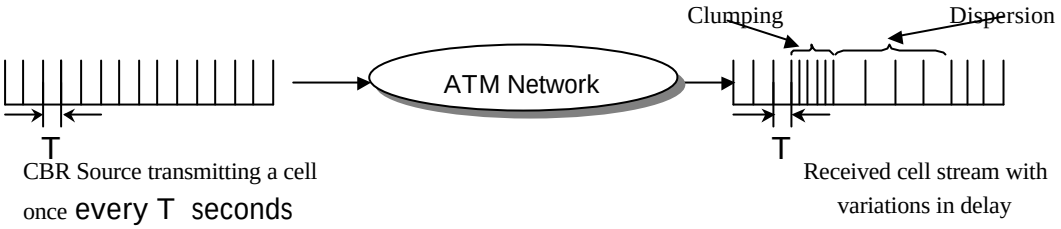

Figure 3 : CBR Test Source Measurement of CDV [2][3]

2.3.Conformance definitions per service categories:

For a given connection , a cell is qualified as conforming or non-conforming to a traffic descriptor through application of an algorithm called the generic cell rate algorithm (GCRA).

The network can implement the GCRA algorithm to police the traffic and take action on some of the non-conforming traffic. When the network finds a non-conforming cell , it can tag or discard the cell, or it can do nothing and let it enter the network as if it were conforming. Tagging refers to the action of degrading a high-priority cell (with CLP=0) to a low-priority cell (with CLP=1). Lowering the priority of a cell makes it ineligible for QoS guarantees, but it may still reach the destination if the network is not overloaded. Discarding simply refers to removing the cell from the stream.

Name	Service category	PCR flow	SCR flow	MCR flow	Non-conforming action	CLR	Max-CTD P2P-CDV
CBR.1	CBR	0+1	N/A	N/A	Discard	0+1	0+1
VBR.1	rt-VBR, nrt-VBR	0+1	0+1	N/A	Discard	0+1	0+1(rt)
VBR.2	rt-VBR, nrt-VBR	0+1	0	N/A	Discard	0	0(rt)
VBR.3	rt-VBR, nrt-VBR	0+1	0	N/A	Tag	0	0(rt)
ABR.1	ABR	0	N/A	0	Discard	0	N/A
GFR.1	GFR	0+1	N/A	0	Discard	0	N/A
GFR.2	GFR	0+1	N/A	0	Tag	0	N/A
UBR.1	UBR	0+1	N/A	N/A	Discard	N/A	N/A
UBR.2	UBR	0+1	N/A	N/A	Tag	N/A	N/A

Table 1: Conformance definitions per service categories [1].

Table 1 [1] summarizes the conformance definitions that can be supported for each service category. The conformance definition also indicates which action the network can take for cells that are judged non-conforming. The possible actions are to discard or tag the cell, or let it enter the network as conforming (i.e.,do nothing) . If the cell enter the network as conforming , it is eligible for QoS (e.g., enough resources need to be allocated for all the conforming cells entering the network).
For the CBR service category , there is a single conformance definition that treats all the CLP cells equally ; therefore the CBR conformance definition is CLP transparent.
For the VBR service category , the VBR.1 conformance definition is fully CLP transparent.

3. Analyzing Cell Conformance

The generic cell rate algorithm (GCRA) is a theoretical algorithm used to define what it means to conform to the traffic descriptors. If the arrival rate is within the contracted rate, taking into account potential jitter, then the cell is qualified as conforming; otherwise it is non-conforming.

3.1. Conformace for the CBR Service

In the case of the CBR service, the conformance definition applies to the peak cell rate of the aggregate traffic. If a cell arrives earlier than 1/PCR with respect to the previous cell, then the arrival rate exceeds the contracted rate and the cell is non-conforming.
However, if multiple connections are multiplexed together on a link, the initial traffic pattern can be disturbed or jittered, or cell delay variation can be introduced (see fig.2). Because of this phenomenon, this simple conformance test cannot be applied; otherwise , conforming traffic that encountered jitter might be treated as non-conforming.
To account for jitter , a tolerance factor is introduced to determine conformance . This tolerance is referred to as cell delay variation tolerance (CDVT).
The generic cell rate algorithm provides a means for applying this test on a per cell basic. The GCRA has two parameters, an increment (I =1/PCR) and a limit (L=CDVT) [5].
The GCRA(I,L) can be expressed as a leaky bucket algorithm or as a virtual-scheduling algorithm.

3.1.1. Analyzing using Leaky Bucket Algorithm

The leaky bucket algorithm is based on the following analogy. A bucket (B) fills with I units every time a conforming cell arrives and continuously leaks one unit every unit of time. The bucket has finite capacity of L. If at cell arrival the bucket capacity is less than or equal to L then the cell is conforming; otherwise it is non-conforming. The bucket overflows when cells arrive at a rate faster than the drain rate. The overflowing cells are non-conforming. The algorithm is triggered by the arrival of a cell, so fill and drain are performed according to the previous arrival time of a conforming cell (last conformance time, or LCT). That is , at the arrival of the cell at time t_a , the bucket drains by (t_a – LCT) , which is equivalent to continuously leaking the bucket by one unit every unit of time. A negative bucket results from a cell arriving later than expected. In this case, the bucket is reset to zero to prevent accumulation of credits, which would allow for eventual generation of large bursts. If the cell is found to be conforming, the bucket is filled by I. At the arrival of the first cell at the time t_a , B = 0 and LCT = t_a . The algorithm is applied to subsequent cell arrivals as depicted in fig.4.

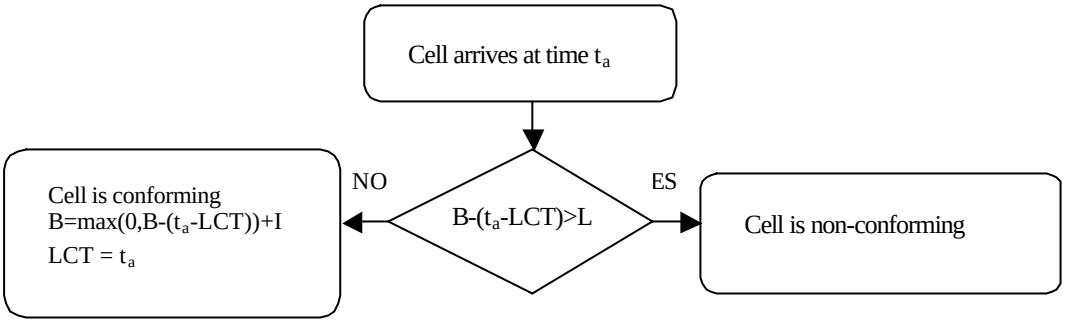

Figure 4: Leaky bucket algorithm for CBR (PCR of aggregate flow)

3.1.2. Analyzing using Virtual Scheduling Algorithm

The virtual Scheduling algorithm keeps track of when the next conforming cell is expected to arrive , the theoretical arrival time (TAT) . When a cell arrives at time ta, if t_a is greater than TAT-L then the cell is conformance; if it is earlier then the cell is non-conforming . The TAT is always incremented by 1/PCR , unless the cell arrives later than TAT in which case it is set to t_a . At the arrival of the first cell at time t_a , TAT is initialized to t_a . Subsequent cell arrivals are subject to the algorithm presented in Fig.5.

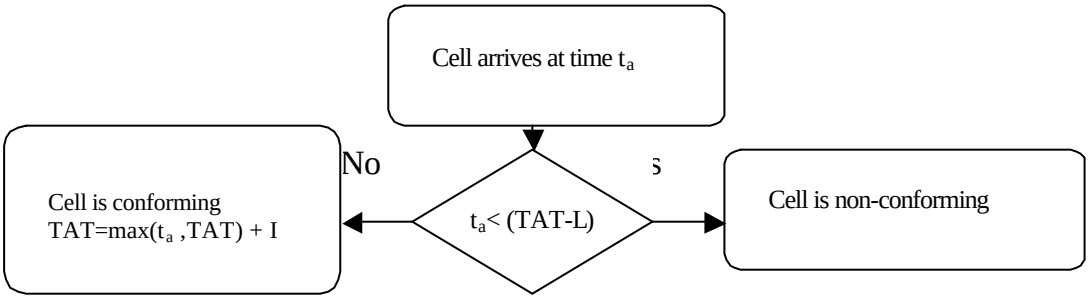

Figure 5 : Virtual scheduling algorithm for CBR (PCR of aggregate flow)

The following example demonstrates how the leaky bucket and virtual-scheduling algorithm behave . A conformant cell stream (PCR of one fourth of line rate) has been jittered by the ATM network (cloud), and the resulting stream is depicted in Fig.6.

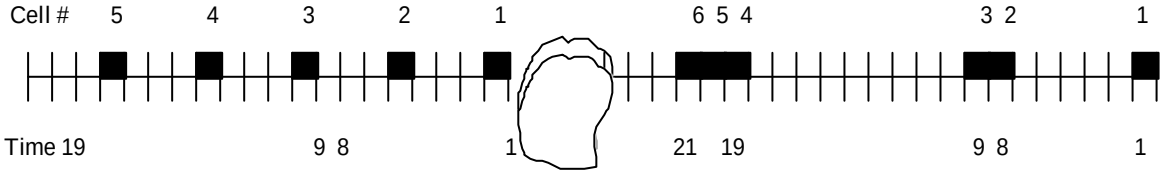

Figure 6 : Cell stream originally equally spaced every 4 time units and jittered.

Cell#	t_a	TAT	TAT-t_a	B	LCT	B-(t_a-LCT)	Conformance
1	1	1	0	0	1	0	Yes
2	8	5	-3	4	1	-3	Yes
3	9	12	3	4	8	3	No
4	19	12	-7	4	8	-7	Yes
5	20	23	3	4	19	3	No
6	21	23	2	4	19	2	Yes

Table 2 : Evolution of the leaky bucket and virtual scheduling on the cell stream of Fig.6. I=4, L=2.

Table 2 demonstrates the evolution of the algorithms based on the cell arrivals in Fig.6, assuming a CDVT of two time units. The resulting cell stream is presented in Fig.7, where gray cells are detected as non-conformant. In this case two cells are judged non-conforming.

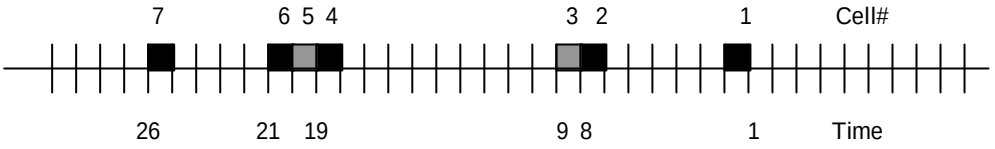

Figure 7 : Cell stream after conformance monitoring with CDVT=2. Gray cells are non-conforming.

Cell#	t_a	TAT	TAT-t_a	B	LCT	B-(t_a-LCT)	Conformance
1	1	1	0	0	1	0	Yes
2	8	5	-3	4	1	-3	Yes
3	9	12	3	4	8	3	Yes
4	19	16	-3	7	9	-3	Yes
5	20	23	3	4	19	3	Yes
6	21	27	6	7	20	6	No

Table 3 : Evolution of the leaky bucket and virtual scheduling on the cell stream of Fig.6. I=4, L=3.

Since the original cell stream was conforming, the CDVT should be set large enough to make all cells conform. Table 3 shows the behavior, assuming the CDVT is increased to three time units.

The resulting cell stream is depicted in Fig.8, where the gray cells are non-conforming.

In order to detect all cells as conformant, the algorithm needs to set CDVT to six time units.

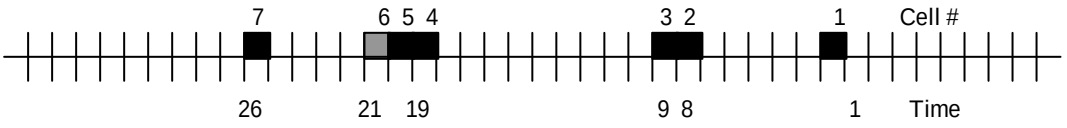

Figure 8 : Cell stream after conformance monitoring with CDVT=3. Gray cells are non-conforming.

3.2. Conformance for the VBR Service

For the VBR service, the conformance is defined on both the SCR and the PCR. The PCR conformance is always defined on the aggregate of the cells. Depending on the type of conformance definition, the SCR may be defined on the aggregate (VBR.1) or on the CLP=0 flow only (VBR.2 and VBR.3).

The SCR is evaluated by the same algorithm as for the PCR. In the case of SCR, a burst tolerance (BT) is defined to allow the connection to burst up to a maximum burst size (MBS) of cells at the PCR. The BT is calculated as [4]

$$BT = (MBS - 1) \times (\frac{1}{SCR} - \frac{1}{PCR})$$

The GCRA for the SCR is the same as for PCR, but in this case the increment is set to 1/SCR and the limit is set to BT + CDVT. As for PCR, the CDVT must also be included to account for the jitter. The SCR is always defined in conjunction with the PCR; therefore, in order to monitor conformance to SCR, one also needs to monitor the conformance to the PCR.

In the case of the VBR.1 conformance definition, a cell that conforms to the PCR must also conform to the SCR in order to be a conforming cell. For the VBR.2 and VBR.3 conformance definition, only cells with CLP = 0 that conform to the PCR need also conform to the SCR in order to be a conformant cell. Any CLP = 1 cells that conform to the PCR do not need to conform to the SCR in order to be conformant. The state of the algorithms are updated only if the cell conforms to both GCRAs. The resulting combined algorithm is referred to as dual leaky bucket and dual virtual scheduling.

3.2.1. Analyzing using Dual Leaky Bucket Algorithm

The dual leaky bucket algorithm used to verify conformance for the VBR.1 definition is depicted in Fig.9. This algorithm behaves like the single leaky bucket with limit and increment parameters for PCR & SCR, that is L_p, I_p , L_s , I_s , respectively. Bp & Bs are the bucket sizes for the PCR and SCR. At the arrival of the first cell at time ta, Bs = Bp = 0, LCT = ta. Since the conformance definition is CLP transparent, only one LCT parameter is required.

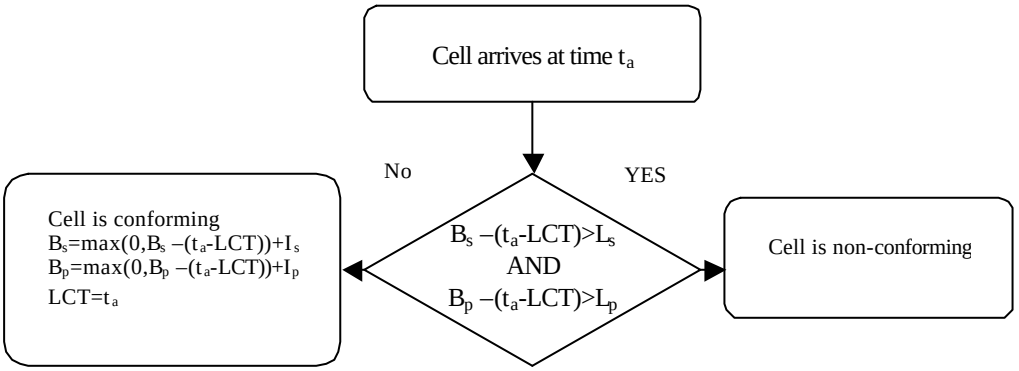

Figure 9 : Dual leaky bucket algorithm for VBR.1

The dual leaky bucket algorithm used to verify conformance for the VBR.2 or VBR.3 definition is depicted in Fig.10. Again, this algorithm behaves like the single leaky bucket . In this case, two LCT parameters, LCTp and LCTs, are needed to keep track of the last conformance to PCR. At the arrival of the first cell at time ta , Bp = Bs = 0 and LCTp = ta. At the arrival of the first CLP = 0 cell at time ta_0 , $LCT_s = ta_0$.

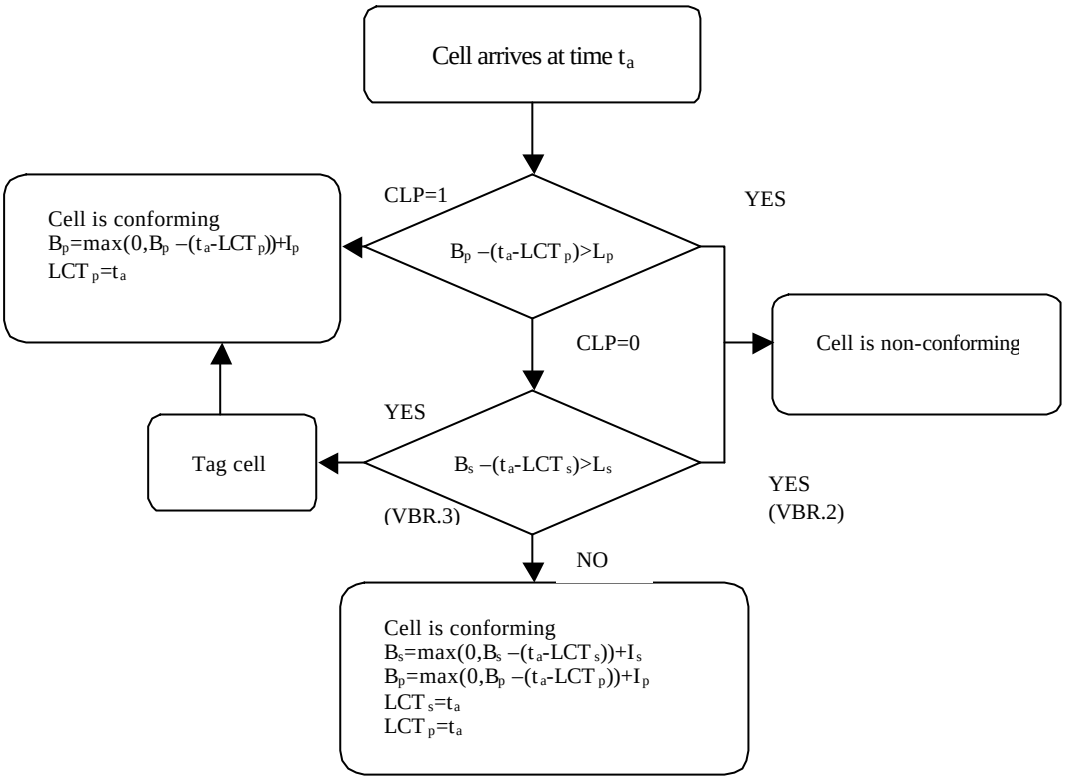

Figure 10 : dual leaky bucket algorithm for VBR.2 and VBR.3

3.2.2. Analyzing using Dual Virtual-Scheduling Algorithm

Figures 11 and 12 present the dual virtual-scheduling algorithm applied to the VBR.1 and the VBR.2/VBR.3 conformance definitions, respectively. Two theoretical arrival time parameter, TATp and TATs, are needed to monitor the PCR and SCR , respectively.

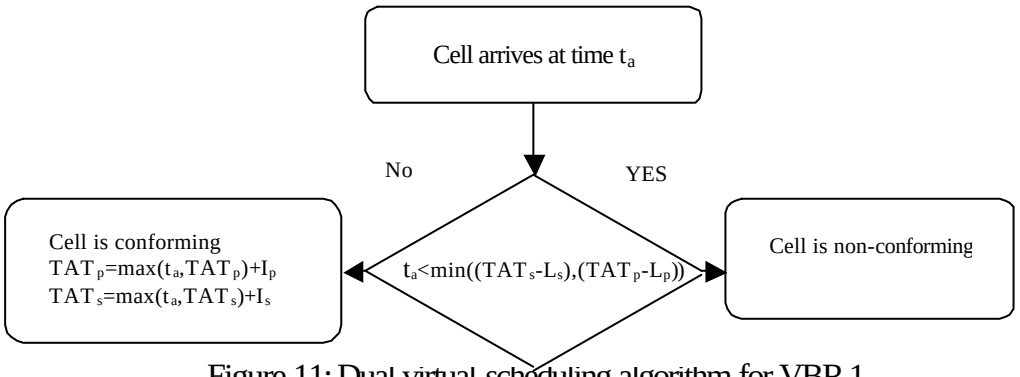

Figure 11: Dual virtual-scheduling algorithm for VBR.1

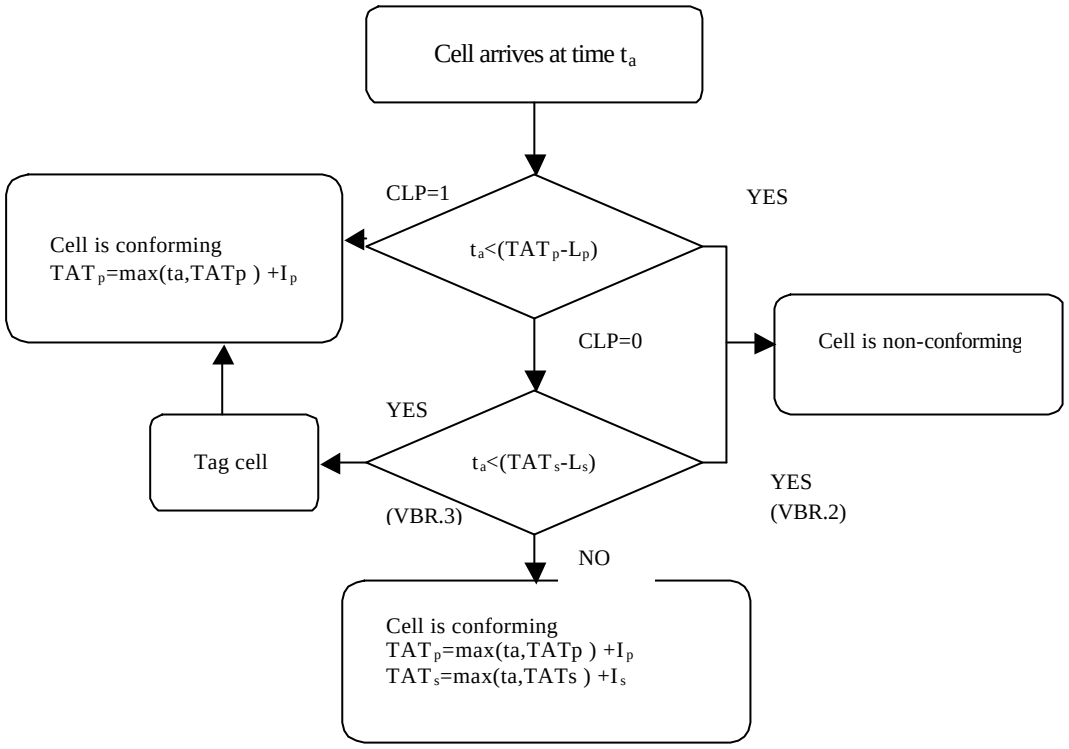

Figure 12: Dual virtual-scheduling algorithm for VBR.2 and VBR.3

4. Conclusions

The above examples demonstrate the outcome of applying different conformance definitions to incoming traffic. The VBR.1 results in more discarded cells without differentiating the incoming CLP bit.

The VBR.3 conformance definition results in fewer discarded cells but a higher number of cells with CLP set to one . For VBR.1, bandwidth needs to be allocated for the aggregate traffic ; in the case of VBR.2 and VBR.3, bandwidth is only allocated for the CLP = 0 cells.

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