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To: **IEEE P1394.1 Working Group**

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Re.: **Traffic Specification and Bridge Resource Reservation in IEEE1394 Networks for Isochronous Streams**

In July 1999 P1394.1 working group meeting we identified a need to specifying traffic parameters beyond the peak bandwidth requirements while requesting an isochronous connection to be setup across bridges. The rationale behind this was twofold. First, the type of multimedia traffic expected to pass through the bridges is likely to be bursty and hence, the peak bandwidth requirement alone would not allow a bridge to efficiently manage its resources. Second, bridges may not operate at the full IEEE1394 rate due to physical media or some other limitations. Probable examples of such limited-bandwidth bridge fabrics include wireless media and twisted-pair phone lines. Hence, there is a need to describe the traffic characteristics of an isochronous stream more accurately to the bridge management firmware.

In July meeting additional traffic parameters were proposed which included: Average and peak bandwidths required, maximum burst length, and minimum bandwidth required. It was noted that depending on the buffer space and link capacity availability, delay encountered by one stream might differ from another. In this document we first elaborate the need for such traffic specification parameters and then we provide some theoretical background on how these traffic parameters can be used to manage bridge resources. Please note that, the theoretical background is provided for information only. Our intention is not to standardize a particular traffic scheduling or buffer management policy – those are best left out of the standards specifications. However, it is our desire to agree on a comprehensive traffic descriptor that would allow a wide range of bridge resource policies to be implemented – from the simplest one based on peak rate to a quite sophisticated one.

Traffic Burstiness

In BR056R00 we presented an example of MPEG video transport stream that generates 4 (four) 24-byte data blocks in most of the isochronous cycles, but occasionally 8 data blocks are generated in some isochronous cycles. According to the IEEE1394-1995 specification, the source has to setup an isochronous connection at 8 data blocks/isochronous cycle rate. Although this wastage of 50% of capacity may be tolerated in a 400Mbps 1394 bus, it would be highly undesirable for slower bridge devices. Today, most of the video traffic is encoded at variable bit rate (VBR) and constant quality. For example, bit-stream generated out of a DVD source has a typical average rate of 3.5 Mbps although its peak rate can be as high as 10.8Mbps (see Table 5 in [1]). In [2] Table 1, it is reported that for various popular movies and sports sequences standard deviation of *I*-frame sizes are larger than their average values which indicates highly bursty I-frame traffic.

Traffic & Quality of Service (QoS) Descriptors

We borrow from the recent literature on support of QoS functions in broadband ATM and IP networks (See [7] & [8], respectively) for selecting and proposing the traffic contract parameters to be used while requesting an isochronous connection set-up. Later in this document we show how these parameters can be employed by resource management policies to decide whether to accept a connection request, and if so, how to compute effective link and buffer capacities for the stream. Traffic parameter specification similar to the one described below is required of real-time VBR ATM traffic (rt-VBR). Traffic parameter specification requirement for guaranteed service IP traffic is similar.

Peak bit rate (PBR) - In our case this can be defined in terms of maximum number of bits transmitted in an isochronous cycle,
Sustained bit rate (SBR) – Average bit rate generated by the source,
Minimum Burst Size (MBS) – Maximum number of bits that can be generated at peak rate,
Maximum Transfer Delay (MTD) – Upper bound of transfer delay through a bridge,
Maximum Transfer Delay Variation (MTDV) (due to network jitters), and,
Frame Loss Probability (FLP) – Due to buffer overflow.

From these parameters, link capacity and buffer space requirements will be computed. Also note that, bursts have to be spaced by a minimum distance for the traffic to be conforming to its contract. Burst tolerance, in units of time, is given by:

$$\tau_s = (MBS - 1)\left(\frac{1}{SBR} - \frac{1}{PBR}\right)$$

Then, over any closed time interval *t*, the maximum number of bits that can be generated at up to the peak rate is bounded by [7, Annex B4]:

$$N(t) \leq \min(\lfloor 1 + (t + \tau_s) \quad SBR \rfloor , \lfloor 1 + t * PBR \rfloor)$$

In the "token bucket" terminology, traditionally used in the ATM flow control space, the *N(t)* can also be expressed as [7]

$$N(t) = Min(M + PBR * t \quad , \quad b + SBR * t)$$

where *b* is the depth of the token bucket.

On-Off Traffic Model

For computation of link capacity and buffer space requirements in order to support a requested QoS level often a two-state on-off Markov model of the source is used. In this model it is assumed that the source is either in on state or in off state. In on state the traffic is sourced at peak rate and on off state no traffic is generated. Duration of the on and off-states depends on the peak rate, average rate, and burst duration [6]. This model essentially captures the worst possible case, *i.e.*, most bursty, behavior of the traffic source under the specified traffic contract. Thus, the capacity and buffer requirements obtained from employing such a model are their conservative estimates. Note that this model assumes exponential distribution of the duration of the on and off states.

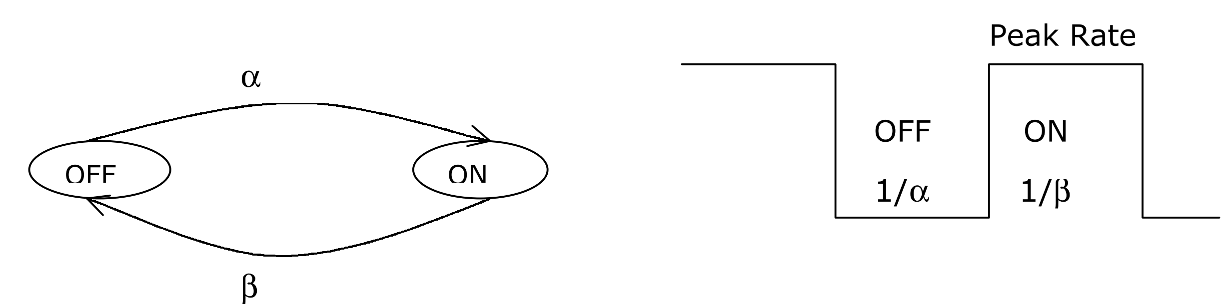

Fig 1. On-Off Model.

Bridge Resource Management

Depending on the video sequence, as much as 8-40% savings on network resources can be achieved. (See [1], Table 7). There are several different approaches documented in the literature to compute the required bandwidth and buffer space in order to support a desired QoS for a given set of traffic parameters. These approaches typically involve computing the *Effective Bandwidth (EBW)* of the traffic stream based on *General Processor Sharing* approach. Based on two-state fluid flow model of the source, its *effective* bandwidth is conservatively estimated to be [1]:

$$EBW_{fluid\,model} = \frac{C - B_{mux} + \sqrt{(C - B_{mux})^2 + 4\rho C B_{mux}}}{2C/PBR}$$

where,

$C = \ln(1/FLP) * MBS * (1 - \rho) * PBR$
B_{mux} = Buffer size of statistical multiplexor, and
ρ = source utilization

Other approaches for calculating EBW includes Gaussian approximation of the total traffic and Erlang- distribution of the on/off periods.

Now consider an isochronous connection request is to be routed via *H* hops and the minimum bandwidth guaranteed for the connection at each of the link is *R.* Then the end-to-end delay for the isochronous stream is upper bounded by [5]:

$$\hat{D} = \frac{b}{R} + \frac{(H-1)M}{R} + \sum_{h=1}^{H} \frac{L_{\max,h}}{\gamma_h}$$

where,

b = token bucket depth which is related to the maximum burst size,

M = maximum frame size for the isochronous stream,
γ_h = speed of link h, and
$L_{max,h}$ = maximum packet length allowed over link L. Note that this bound is obtainable by employing Packetized Generalized Processor Sharing scheduling policy which is rather complex.

Preceding discussions show the availability of some of the tools for determining the required network resources for a requested flow. In fact a wide range of bridge resource management can be implemented depending on the applications and the need to utilize the available bridge fabric capacity efficiently (See [3] for a survey). This range does include the simplest approach of reserving resources at peak rate. Another quite conservative resource allocation approach would be to use the maximum burst length at peak rate and the minimum time between two consecutive bursts for computing the bandwidth and buffer requirements for a given FLP and MTD.

This discussion does not provide an exhaustive list of all the approaches that can be used to efficiently support QoS attributes in packet networks. Rather, the goal was to briefly introduce some of the basic ones to show that such tools do exist. Again, we are primarily interested in standardizing the traffic and QoS parameters carried in isochronous connection setup requests.

References

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