VBR over VBR: the Homogeneous, Loss-free Case

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Abstract
We consider the multiplexing of several variable bit rate (VBR) connections over one variable bit rate connection where the multiplexing uses a multiplexing buffer of size B. The VBR trunk is itself a connection and has a multidimensional connection descriptor, reflecting peak and sustainable rates. Given a cost function for the VBR trunk and a connection admission control (CAC) method for the input connections, we focus on the problem of finding the VBR trunk connection descriptor that minimizes the cost function and is able to accept a given set of VBR input connections. First, we show that, under reasonable assumptions on the cost function, the optimization problem can be reduced to a simpler one. Then we consider the homogeneous, loss-free case, for which we give an explicit CAC method. In that case, we find that, for all reasonable cost functions, the optimal VBR trunk is either of the CBR type, or is truly VBR, with a burst duration equal to the burst duration of the input connections. We motivate this study by showing that the optimal peak cell rate is fixed for a given B (thus for a CBR trunk), and a VBR choice can only be an improvement. Lastly, we take as example of cost function the equivalent capacity of the VBR trunk. Those results are expected to form the basis for a general method for a connection manager at a multiplexing node in an integrated services packet network.

Keywords: CAC, VBR, Virtual Path, Virtual Trunk, ATM, Integrated Services

1 Introduction
1.1 VBR over VBR, multiplexing and virtual trunks

We consider the multiplexing of several variable bit rate (VBR) connections (called "the input connections") over one variable bit rate connection (called "the VBR trunk"). This occurs for example with ATM when a number of VBR virtual channel connections (VCCs) are multiplexed over one virtual path connection (VPC) [1] which is also of the VBR type. Another example is the multiplexing of several IP flows with reservations (using a protocol such as RSVP [2] or ST-II [3]) over one ATM VCC.

We are interested in such multiplexing scenarios since we believe that reducing the number of connections (or reserved flows if RSVP is used) is a key feature that will be needed in all large scale networks. This is because connection handling cost, especially network management overhead, processing and memory is not negligible and increases almost linearly with the number of connections handled at one point. One solution is to aggregate connections at all points where this is possible. Connection aggregation simplifies all aspects of connection handling, provided that it is possible to dynamically change the attributes of the multiplexed connections [4] [5]. Aggregation can take place: (1) at an ATM node performing aggregation of VCCs over a VPC; (2) at an IP router aggregating several reserved flows over one ATM connection; (3) at an IP router aggregating several reserved flows over one reserved flow (tunneling). We call Virtual Trunk (VT) the connection that multiplexes a number of other connections, the word "trunk" refers to the fact that those connections also have attributes of network internal links, as defined for example with P-NNI [6]. In case (1), VTs are VPCs, in case (2), VTs are VCCs, and in case (3), they are IP tunnels with reserved resources. In this paper we use mainly ATM terminology, which applies strictly to case (1) only (VT can thus be equated to VPC). Translation to cases (2) and (3) should however be straightforward. We call multiplexer the node that multiplexes several input connections on one output VT.

Virtual trunks have traditionally been considered as Constant Bit Rate connections, though this restriction is not mandatory. In contrast, using other traffic types has obvious benefits. In this paper, we consider VTs of the VBR type. The rationale for using VBR VTs is the following. Integrated services packet networks provide resource reservation; however, they will not allocate its peak rate to every individual con-