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(71) Applicant: FUJITSU LIMITED [JP/JP]; 1–1, Kamikodanaka 4–chome, Nakahara–ku, Kawasaki–shi, Kanagawa 211–8588 (JP).

(72) Inventors: HOLZWORTH, Herbert, Paul; Fujitsu Network Communications, Inc., 1000 St. Albans Drive, Raleigh, NC 27609 (US). KAKUMA, Satoshi; Fujitsu Limited, 1–1, Kamikodanaka 4–chome, Nakahara–ku, Kawasaki–shi, Kanagawa 211–8588 (JP). LIPP, William; 317 Saint Ronan Street, New Haven, CT 06511 (US). DEVAL, Gary; Fujitsu Network Communications, Inc., 1000 St. Albans Drive, Raleigh, NC 27609 (US).

(74) Agent: HENRY, Mark, J.; Staas & Halsey LLP, Suite 500, 700 Eleventh Street, N.W., Washington, DC 20001 (US).

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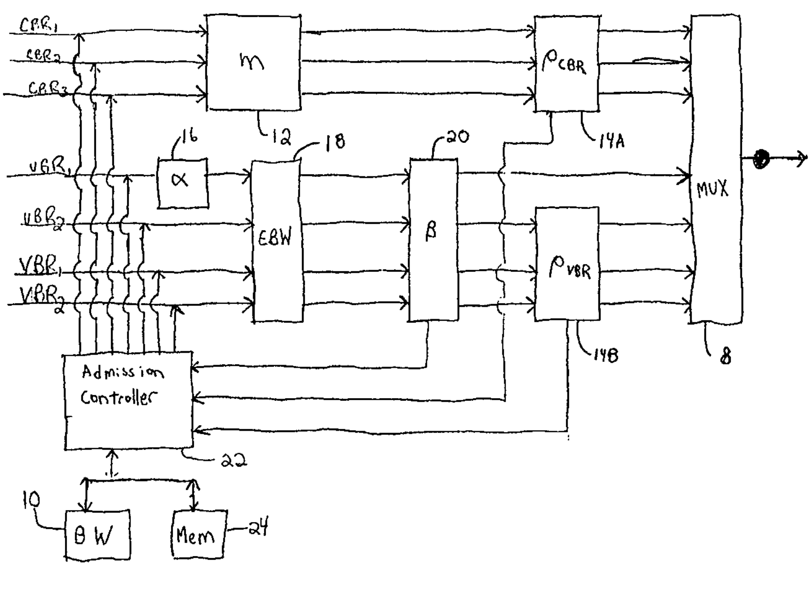
(54) Title: ADJUSTABLE CONNECTION ADMISSION CONTROL METHOD AND DEVICE FOR PACKET–BASED SWITCH



(57) Abstract

An adjustable connection admission control method and device (22)for packet based switches assigns equivalent bandwidths to variable speed connections. The equivalent bandwidths (18) of the variable speed connections are increased or reduced by a scaling factor (20) to achieve an assigned bandwidth. The method and device determines whether to accept or refuse new variable speed connections based on whether the sum of equivalent bandwidths for existing variable speed connections and new variable speed connections exceeds the bandwidth available to variable speed connections. The connection admission control method and device also determines whether to accept or refuse new constant speed and new unspecified connections.

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ADJUSTABLE CONNECTION ADMISSION CONTROL METHOD AND DEVICE FOR PACKET-BASED SWITCH

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based and claims priority to U.S. Provisional Application No. 60/105,836, filed October 26, 1998.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to controlling the admission of new connections to a packet-based switch. More specifically, the present invention relates to an adjustable connection admission control system for a packet-based switch.

2. Description of the Related Art

Fig. 1 is a schematic view of a conventional packet-based switching system. In Fig. 1, traffic flows from left to right. The interfaces IF1 through IF4 are represented on both the left and right side of a switching matrix. The left interfaces show traffic entering the switching matrix, and the right interfaces show traffic exiting the switching matrix. A user supplies traffic to an interface on the left and takes traffic from an interface (the same interface) on the right. The user may contract for the type of connection needed. For example, the user may contract for a constant bit rate ("CBR") connection, a variable bit rate ("VBR") connection or an unspecified bit rate ("UBR") connection. The user might provide traffic information such as a sustained cell rate, a peak cell rate, a maximum burst size, etc. This traffic information provides the switch with information regarding the maximum bounds for the user's traffic. However, it would be unusual for all users to operate at the maximum bounds. The traffic rate is expected to be bursty and somewhat unpredictable, and the switch can accommodate all traffic that fits with the maximum bounds defined by the traffic information. This presents a problem in resource allocation. That is, it is difficult to determine how many connections can be handled by a switch when the traffic rate of each connection is variable.

One way to address the resource allocation problem is for the switch to assign a nominal bit rate to each requested connection. The number of permissible connections is determined from the nominal bit rate using a connection admission control (also referred to as "CAC") system. CAC must be done for each point of possible congestion. In Fig. 1, the circles represent the points of possible congestion, where connection admission control is used. In general, CAC is done at each egress points. For example, if all users connected to interface 1 transmit at their maximum permissible rate, there may be congestion in the link carrying traffic from interface 1 to the switching matrix. Conventional connection admission control is described in U.S. Patent Nos. 5,949,757; 5,936,958; 5,751,691; 5,696,764; 5,583,857; 5,555,265 and 5,341,366, which are hereby incorporated by reference.

Connection admission control is based on traffic descriptors such as peak cell rate, sustained cell rate, maximum burst size, cell delay variation tolerance, etc. The CAC mechanism allocates the minimum switch resources necessary to meet the requirements of the requested connection. If sufficient resources are not available, CAC will not complete the connection. Connection admission control is done in different ways for different traffic classes (also referred to herein as different connection types). That is, constant bit rate, variable bit rate and unspecified bit rate connections are treated differently. For non-constant bit rate service, CAC provides statistical multiplexing. Bandwidth for variable bit rate connections is allocated by determining an equivalent bandwidth ("EBW") based on the peak cell rate sustained cell rate and maximum burst size. EBW is also determined based on the link between the switch components being considered. For the link, parameters such as link speed, buffer size, buffer read out rate, and buffer structure (shared or individual) are considered.

To allocate bandwidth for the significantly different types of traffic, connection admission control requires complex mathematical manipulation of data. To provide superior service, it is desirable to allocate resources conservatively. On the other hand, to accommodate more users, it is desirable to allocate resources aggressively. Different switch operators desire a more or less aggressive approach to resource allocation. However, connection admission control is determined in advance by the switch manufacturer. Because of the complexities associated with connection admission control, it cannot be altered by the individual switch operator.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to allow individual switch operators to customize their switch to allocate resources more or less aggressively.

This and other objects are accomplished by providing an adjustable connection admission control method and device for packet-based switches that assigns equivalent bandwidths to variable speed connections. Equivalent bandwidths are assigned to variable speed connections. The equivalent bandwidths of the variable speed connections are increased or reduced by a scaling factor to achieve an assigned bandwidth. The scaling factor can be adjusted to change the assigned bandwidths. The method and device determine whether to accept or refuse new variable speed connections based on whether the sum of assigned bandwidths for existing variable speed connections and new variable speed connections exceeds the bandwidth available to variable speed connections. The bandwidth available to variable speed connections is increased or reduced by a variable speed traffic factor. The variable speed traffic factor can be adjusted.

The connection admission control method and device also determines whether to accept or refuse new constant speed connections. To do this the sum of bandwidths for existing and new constant speed connections is obtained. If the sum of bandwidths for existing and new constant speed connections exceeds a maximum factor, the bandwidth available to constant speed connections is reduced by a constant speed traffic factor. The maximum factor and the constant speed traffic factor can be adjusted.

The connection admission control method and device also determines whether to accept or refuse new unspecified connections. At least a portion of the unspecified connections do not have a sustained cell rate. The sustained cell rate is determined by multiplying a peak cell rate by an SCR factor, which factor can be adjusted. Equivalent bandwidths are also assigned to unspecified connections. The equivalent bandwidths of the unspecified connections are increased or reduced by the scaling factor to achieve an assigned bandwidth. New unspecified connections are accepted or refused based on whether the sum of assigned bandwidths for existing and new unspecified connections exceeds a bandwidth available to unspecified connections.

An original scaling factor is maintained for all existing variable speed connections. A new scaling factor is used to allocate bandwidth for all new variable speed connections. When an existing variable speed connection is terminated, the amount of assigned bandwidth freed by the termination is determined based on the original scaling factor. The freed up resources, however, are reallocated based on the new scaling factor.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be readily understood by reference to the following description of preferred embodiments described by way of example only, with reference to the accompanying drawings in which like reference characters represent like elements, wherein:

Fig. 1 is a schematic view of a conventional packet-based switching system; and

Fig. 2 is a schematic view of an adjustable connection admission control device according to a preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 2 is a schematic view of an adjustable connection admission control device according to the present invention. The device shown schematically in Fig. 2 would be used at each point of possible congestion, where connection admission control is to be performed. That is, the device shown schematically in Fig. 2 would be used in Fig. 1 at the egress points represented by circles. Fig. 2 shows a plurality of connections being multiplexed onto a single link by multiplexer 8. In describing the present invention, the terms "bandwidth" and "bit rate" are used synonymously, both possibly having units of bits per second.

In the device shown in Fig. 2, different types of connections are treated independently. That is, the total bandwidth available at the egress point, the physical capacity of the link where congestion could occur, is allocated by bandwidth allocator 10 to the different types of connections. New connection(s) of a given type (CBR, UBR or VBR) may be refused if the additional connection(s) will result in a bandwidth which exceeds that allocated for the connection type. Bandwidth allocator 10 can reallocate the bandwidth available at the egress point. For example, if 1 Gbps of bandwidth is available at the egress point, 300 Mbps could be allocated to CBR connections, 300 Mbps could be allocated to UBR connections and 400 Mbps could be allocated to VBR connections. If the volume of

CBR traffic is large and the volume of VBR traffic is small, the bandwidth allocator 10 could change the allocation so that 500 Mbps would be allocated to CBR connections and 200 Mbps would be allocated to VBR connections. Allocation allows for CAC to be performed independently for each type of connection. Reallocation minimizes the number of connections that are refused.

Fig. 2 shows three constant bit rate connections CBR_1-CBR_3 received at a first controller 12. The bandwidth allocated for a constant bit rate connection must at least equal the nominal bandwidth (bit rate) of the CBR connection. If the number of CBR connections is fewer than a maximum number m, the first controller 12 signals CBR traffic controller 14A to operate at 100 % efficiency. The value of m can be adjusted varied by the switch operator when the switch is online (without dropping connections) or offline. At 100 % efficiency, the entire bandwidth allocated to CBR connections can be used. That is, new CBR connections can be established if the following equation is satisfied:

$$\Sigma\ CBR \leq TBW_{CBR} \bullet \rho_{CBR} \qquad (1)$$

where Σ CBR is the sum of the nominal bit rates for all existing and new CBR connections. TBW_{CBR} is the bandwidth allocated to CBR connections by bandwidth allocator 10. $\rho_{CBR.}$ is a CBR traffic parameter, which is equal to "1" for 100 % efficiency.

If the number of CBR connections exceeds the maximum number m, first controller 12 communicates with CBR traffic controller 14A to reduce the effective bandwidth available to CBR connections. ρ_{CBR} may be set to 1 for maximum efficiency, but would be reduced to a number between 0 and 1 when the number of CBR connections exceeds the maximum number m. By reducing the value of ρ_{CBR}, the switch takes into account the reduced efficiency. The value of ρ_{CBR} can be adjusted varied by the switch operator when the switch is online (without dropping connections) or offline.

It is important to note that when the value of ρ_{CBR} is reduced while the switch is online, the effective bandwidth available for all CBR connections immediately decreases. Numerically this translates to an over-subscription problem. However, because the actual number of connections has not changed, it is not necessary to release any connections. The general equation to determine whether new CBR connections will be accepted is as follows:

$$CBR_1/\rho_{CBR,1} + CBR_2/\rho_{CBR,2} + CBR_3/\rho_{CBR,3} \ldots + \ldots CBR_n/\rho_{CBR,n} \leq TBW_{CBR} \qquad (2)$$

where CBR_1 to CBR_n are the nominal bit rates for n CBR connections and $\rho_{CBR,1}$ to $\rho_{CBR,n}$ re the CBR traffic parameters for n CBR connections. The above equation (2) takes into account that different connections may have been established using different values for ρ_{CBR} . As mentioned above the value of ρ_{CBR} at peak efficiency (usually 1) will be different from the value of ρ_{CBR} when the number of CBR connections exceeds the maximum number m. Further, the switch operator can manipulate the value of ρ_{CBR} while the switch is online. Usually the switch operator would not change the peak efficiency value of ρ_{CBR} from the default value, 1. However, it is highly possible that the switch operator would change the reduced efficiency value of ρ_{CBR} (greater than m CBR connections) while the switch is online.

For unspecified bit rate UBR connections, the user may or may not specify a sustained cell rate. If the user does not specify a sustained cell rate, the UBR connection is sent to a second controller 16. UBR_1 is sent to second controller 16. At the second controller 16, a sustained cell rate is computed based on the peak cell rate. The sustained cell rate is computed by multiplying the peak cell rate by an SCR parameter α. The SCR parameter α can be adjusted by the switch operator, and according to one implementation, the range for α is $0 \leq \alpha \leq 2$ with granularity of 0.001.

If the UBR connection has a sustained cell rate associated therewith, it is not necessary to supply the connection to the second controller 16. Referring to Fig. 2, UBR_2 has a specified sustained cell rate and is not sent through second controller 16. Both UBR_1 and UBR_2 are eventually sent to EBW device 18 where equivalent bandwidths (EBWs) are determined in a manner similar to that described in connection with the related art. That is, the equivalent bandwidths are determined based on parameters such as sustained cell rate, peak cell rate, maximum burst size, buffer size, egress location, buffer read-out rate, etc. Once the equivalent bandwidths are determined, they are increased or reduced in third controller 20 by a scaling factor β. The scaling factor β can be adjusted by the switch operator when the switch is online (without dropping connections) or offline. New UBR connections are accepted if the following equation is satisfied:

$$EBW_1 \bullet \beta_1 + EBW_2 \bullet \beta_2 + EBW_3 \bullet \beta_3 \ldots + \ldots EBW_n \bullet \beta_n \leq TBW_{UBR} \quad (3)$$

where EBW_1 to EBW_n are the equivalent bandwidths for n UBR connections. β is the scaling factor. By using β_1 to β_n, the above equation (3) takes into account that different values for β may have been used to establish different UBR connections. TBW_{UBR} is the bandwidth allocated to UBR connections by bandwidth allocator 10.

For VBR connections, an equivalent bandwidth is determined by EBW device 18, as described above for UBR connections. Then, the equivalent bandwidth is increased or reduced by the scaling factor β and third controller 20. Next, the VBR connections are sent to VBR traffic controller 14B. Here the amount of bandwidth available for VBR connections may be decreased from the amount allocated by bandwidth allocator 10. The amount of available bandwidth is reduced by the VBR traffic parameter ρ_{VBR} in a manner similar to CBR connections. New VBR connections are accepted if the following equation is satisfied:

$$EBW_1 \bullet \beta_1/\rho_{VBR,1} + EBW_2 \bullet \beta_2/\rho_{VBR,2} + EBW_3 \bullet \beta_3/\rho_{VBR,3} + \ldots + \ldots EBW_n \bullet \beta_n/\rho_{VBR,n} \leq TBW_{VBR} \quad (4)$$

where EBW_1 to EBW_n are the equivalent bandwidths for n VBR connections. TBW_{VBR} is the bandwidth allocated for VBR connections by bandwidth allocator 10. The above equation takes into account that different values of β and ρ may have been used for different VBR connections. ρ_{VBR} may be set independently of ρ_{CBR}. Alternatively, the same value may be used for both ρ_{VBR} and ρ_{CBR}. For all requested connections, admission controller 22 establishes or refuses the new connection. For this purpose, admission controller 22 is connected to CBR traffic controller 14A for CBR connections, to third controller 20 for UBR connections and to VBR traffic controller 14B for VBR connections.

To impart flexibility to the switch, each of the parameters m, $\rho_{CBR,}$ α, β and ρ_{VBR} can be varied independently by the switch operator. If the switch operator wishes to be more or less aggressive than the switch manufacturer, the switch operator can increase or decrease the parameters m, $\rho_{CBR,}$ α, β and ρ_{VBR}. However, the effect of changing one or more of the parameters m, $\rho_{CBR,}$ α, β and ρ_{VBR} on the switch may not be readily apparent to the switch operator. The switch operator may need a trial and error process to fully understand how to achieve his or her goals. However, the bandwidth of existing connections cannot be reallocated unless the existing connections are terminated. Because of quality of service and reliability issues, it is impermissible to terminate connections. Accordingly, a mechanism is necessary to allow a switch operator to vary the connection admission control system when the switch is in use. To this end, the present invention allows the switch operator to vary the parameters m, $\rho_{CBR,}$ α, β and ρ_{VBR} for new connections only, without disturbing existing connections. When an existing connection is terminated, bandwidth is reallocated based on the new parameters m, ρ_{CBR}, α, β and ρ_{VBR}.

When an existing connection is terminated, it is essential that the bandwidth freed up for new connections is equivalent to the bandwidth originally allocated for the connection terminated. Otherwise, bandwidth could be permanently lost or the switch could be overloaded. To keep track of the bandwidth allocated, the admission controller 22 is connected to a memory 24. When a new connection is established, the memory 24 stores the nominal bandwidth allocated for that connection. When the connection is terminated, the memory 24 is used to determine how much bandwidth has been freed up by the termination.

There are two basic cases that need to be considered when changing the CAC parameters while the switch is in operation. First, the allocated bandwidth of existing connections may decrease because of the change. CAC recalculates the bandwidth requirements for effected classes of service at each link (congestion point) within the switch. This process is done stepwise, link-by-link until the recalculation is complete. There is no need to reroute existing connections and there is no strong time dependency between the reallocation of the first and last congestion point. It is therefore be possible to continue processing connections even as the bandwidth is being reallocated.

Second, changing one or more of the CAC parameters while the switch is in operation may cause the allocated bandwidth to increase. This results in a temporary over subscription of capacity. For example, assume that the scaling parameter β is increased from 1 to 2. If the bandwidth available for allocation (TBW•ρ) is 622 Mbps and 500 Mbps is already allocated for existing VBR connections, the allocated bandwidth for existing VBR connections effectively becomes 10000 Mbps. Although the bandwidth allocated is now greater than the capacity, the actual traffic has not changed. There is therefore no need to drop connections in order to make them fit within the 622 Mbps link. However, no new connections will be accepted through this link since there is no excess capacity available. Eventually, the existing connections will terminate, freeing up bandwidth. When the allocated bandwidth decreases below 622 Mbps, new connections will once again be accepted. This mechanism provides a graceful way for switch operators to tune their system while not disrupting service. This same method works whenever changing any of the CAC parameters m, $\rho_{CBR,}$ α, β and ρ_{VBR}.

The invention has been described in connection with the device shown in Fig. 2. In practice, however, the invention may be implemented with one or more application specific integrated circuits (ASICs), or more likely, with software.

While the invention has been described in connection with the preferred embodiments, it will be understood that modifications within the principles outlined above will be evident to those skilled in the art. For example, the allocation for CBR connections is described as not being reduced by the scaling parameter β, and this is due to the current standards for CBR connections. However, because the bit rates of CBR connections do vary, it is certainly possible that connections analogous to CBR connections would be allocated a reduced bandwidth. The invention is not limited to the preferred embodiments, but is intended to encompass such modifications.

WHAT IS CLAIMED IS:

1. A connection admission control method for a packet-based switching system, comprising the steps of:

assigning equivalent bandwidths to variable speed connections;

increasing or reducing the equivalent bandwidths of the variable speed connections by a scaling factor to achieve an assigned bandwidth;

adjusting the scaling factor to change the assigned bandwidths; and

determining whether to accept or refuse new variable speed connections based on whether the sum of assigned bandwidths for existing variable speed connections and new variable speed connections exceeds a bandwidth available to variable speed connections.

2. A connection admission control method according to claim 1, further comprising the steps of:

increasing or reducing the bandwidth available to variable speed connections by a variable speed traffic factor; and

adjusting the variable speed traffic factor.

3. A connection admission control method according to claim 2, wherein the scaling factor and variable speed traffic factor are adjusted while the packet-based switching system is online.

4. A connection admission control method according to claim 1, wherein the connection admission control method determines whether to accept or refuse new constant speed connections and new variable speed connections, the method further comprising the steps of:

summing existing and new constant speed connections;

if the sum of bandwidths for existing and new constant speed connections exceeds a maximum factor, reducing a bandwidth available to constant speed connections; and

adjusting the maximum factor.

5. A connection admission control method according to claim 4, further comprising the step of:

determining whether to accept or refuse new constant speed connections based on whether the sum of existing and new constant speed connections exceed the bandwidth available to constant speed connections.

6. A connection admission control method according to claim 4, wherein the bandwidth available to constant speed connections is reduced by a constant speed traffic factor if the sum of bandwidths for existing and new constant speed connections exceeds the

maximum factor, the method further comprising the step of adjusting the constant speed traffic parameter.

7. A connection admission control method according to claim 6, wherein the scaling factor, the maximum factor and the constant speed traffic factor are adjusted while the packet-based switching system is online.

8. A connection admission control method according to claim 1, wherein the connection admission control method determines whether to accept or refuse new unspecified connections and new variable speed connections, at least a portion of the unspecified connections not having a sustained cell rate, the sustained cell rate being determined based on an SCR factor, the method further comprising the step of adjusting the SCR factor.

9. A connection admission control method according to claim 8, wherein the sustained cell rate for unspecified connections is determined by multiplying a peak cell rate by the SCR factor.

10. A connection admission control method according to claim 8, further comprising the steps of:

assigning equivalent bandwidths to unspecified connections;

increasing or reducing the equivalent bandwidths of the unspecified connections by the scaling factor to achieve an assigned bandwidth; and

determining whether to accept or refuse new unspecified connections based on whether the sum of assigned bandwidths for existing and new unspecified connections exceeds a bandwidth available to unspecified connections.

11. A connection admission control method according to claim 10, wherein the scaling factor and the SCR factor are adjusted while the packet-based switch is online.

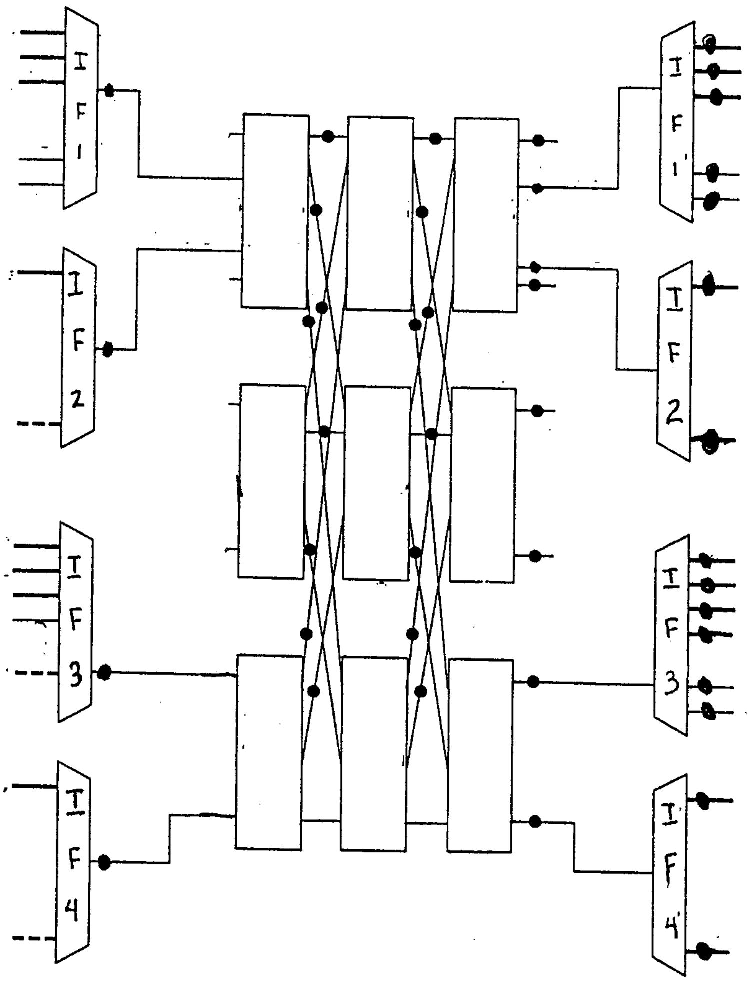
12. A method according to claim 1, further comprising the steps of:

maintaining an original scaling factor for all existing variable speed connections;

using a new scaling factor to allocate bandwidth for all new variable speed connections; and

when an existing variable speed connection is terminated, freeing an assigned bandwidth determined by the original scaling factor and reallocating freed bandwidth based on the new scaling factor.

FIG. 1



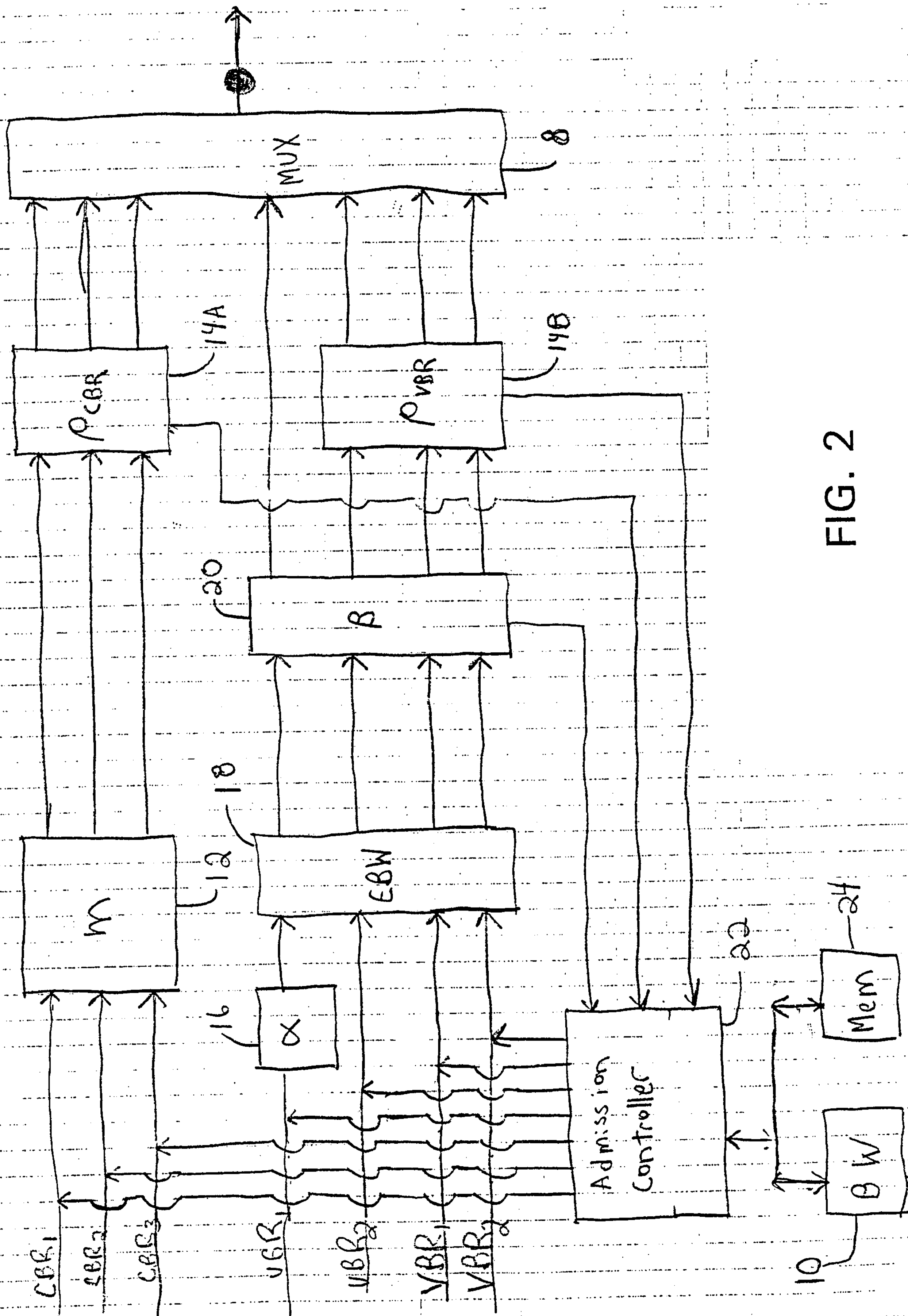

MUX
8
ρCBR
14A
ρVBR
14B
B
20
m
12
EBW
18
α
16
Admission Controller
22
Mem
24
BW
10
CBR1
CBR2
CBR3
VBR1
VBR2
VBR1
VBR2

FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/24999

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :HO4J 1/16, 3/16
US CL :370/229, 231, 232, 233, 235, 465, 468
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 370/229, 231, 232, 233, 235, 465, 468

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

none

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EAST, WEST
search terms: scaling factor, packet switch, adjusting rate, sum of rate, SCR, CBR, VBR

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X, P	US 5,936,940 A (MARIN et al) 10 August 1999, see col. 9, lines 44+, & Fig 6.	1-12
X, P	US 5,909,443 A (FICHOU et al) 01 June 1999, see col. 8, lines 54 + , Fig 9.	1-12
A	US 5,781,531 A (CHARNY) 14 July 1998, see col. 8, lines 34 + & Fig 4.	1-12
X, E	US 6,014,367 A (JOFFE) 11 January 2000, see col. 2, lines 12-36.	1-12

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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