private **cac_flowSafetyMargin: double**

Tunable safety margin used by the CAC algorithm to protect sessions-in-progress from being affected by changes in available network bandwidth.

private **maxMinFlowRate[]: double**

Applies when N rate tariffs exist. This array holds the maximum floor level for each category of service. The value for the costliest category N is stored in maxMinFlowRate[N-1], and for the least costliest in maxMinFlowRate[0]. It is the relative magnitude of these ascending values that matters, not their absolute value. Thus the actual maximum floor flow rate for category k is given by server.maxFlowRate * (server.maxMinFlowRate[k-1] /server.maxMinFlowRate[N-1]). Similarly, the maximum floor flow rate for category N is server.maxFlowRate.

Has:

public **contains: contentSelection**

public **modulates: channel**

Component: contentSelection (public Class/Interface)

Comment:

Entity represents a video/sound clip or other bounded unit of content. A continuous data feed does not qualify.

Attributes:

private **averagePlayRate: double**

The average rate at which media content is consumed by the client, as computed by dividing the (payload * 8) by the (playTime * 60)

private **playTime: double**

Duration of play of the media content in minutes.

private **payLoad: double**

total size of the content in Mbytes.

Has:

public **is associated with: session**

--- end of entity data model detailed listing ---

The following table summarizes the highlights of the previous detailed description of each entity in Figure 2.

TABLE 1

Entity	**Description**
client 200	Each client is denoted by an associated unique integer index $_{Id}$. The set of active clients is denoted by $\mathbf{S}_{ActiveClients}$. The set of deferred clients is denoted by $\mathbf{S}_{QdClients}$. Incoming clients are expected to select the content they wish to view prior to being queued for dispatch by the CAC sub-system, which requires knowledge of the client's bandwidth requirements, duration of play, and cost of service, all of which may vary according to the selection.

server 220	Servers sit astride a network and can deliver media content through the network to their clients up to a designated maximum flow rate. The server is responsible for accepting or rejecting clients, launching sessions and associated channels for the former, and modulating content flows over all channels in an optimal manner.
channel 210	A channel represents the data path between the server and the client. The channel buffer is typically located near or within the clients viewing station. The flow of content through the channel is set by the flow modulator sub-system.
contentSelection 230	A server will typically act as a repository for media content, which it can deliver to clients upon demand. For our purposes, media content is characterized by its payload and the play duration, which together imply the ***averagePlayRate*** = (payload*8)/(playTime *60). The averagePlayRate is none other than the streaming rate imposed by real-time just-in-time streaming algorithms.
session 240	Every session represents an instance of media content delivery to an associated client over a designated channel. The ***playTimeToGo*** indicates the time remaining before the content is fully played out to the client. The ***payloadToGo*** is the amount of content data as yet undelivered to the channel. A session terminates when this value reaches zero, at which time ***playTimeToGo*** may still be large, according to the capacity, the level of the channel buffer, and the media play rate.

Constraints On Content Flow

[0021] Before referring to more Figures, it is imperative to establish some formulas and problem statements which are used in the methods which follow.

[0022] The flow of content between entities is subject to the following constraints at all times. Buffer levels are always expressed in Mbytes and data rates in Mbits/sec.

(1)$\Sigma_{i \in SactiveClients}$ (client.lookup(i).channel.flowRate) < = server.maxFlowRate

The sum of all channel flows cannot exceed the imposed maximum throughput capacity of the server.

(2)client.lookup(i).channel.flowRate < = client.lookup(i).channel.maxFlowRate for all $\mathbf{i} \in \Sigma_{activeClients}$

The data path from server to client is subject to its own constriction.

(3)client.lookup(i).channel.flowRate < =(client.lookup(i).channel.bufferSize - client.lookup(i).channel.bufferLevel)* 8/60 + client.lookup(i).session.mediaContent.averagePlayRate, for all $\mathbf{i} \in \Sigma_{activeClients,}$

The channel buffer is never allowed to overflow.

(4)client.lookup(i).channel.flowRate < = client.lookup(i).session.payloadToGo * 8/60

for all $i \in \Sigma_{activeClients}$,

Content that does not exist cannot be delivered. (Constraint 1 will ordinarily prevail except at the very end of a session.)

[0023] The constraints listed above are straightforward applications of common sense in relation to the flow of data through constricted channels, out of finite data sources, and into and out of bounded buffers. By contrast, the following constraint, which imposes a minimum channel flow rate instead of a maximum, is less obvious. The minimum value, termed the ***minFlowRate*** is set to the flow rate which, if sustained over the balance of the play time to go (***playTimeToGo***), ensures that all required content will be available when needed -- and no sooner -- until all content is played out. This floor value can be calculated for $i \in \Sigma_{activeClients}$ by the formula:

(5)client.lookup(i).session minFlowRate =(client.lookup(i).session.payloadToGo * 8)/ (client.lookup(i).session.playTimeToGo * 60)

Accordingly, the flow rate on the right-hand-side is termed the just-in-time (JIT) flow rate (f^{JIT}).

Thus:

(6)client.lookup(i).channel.flowRate >= client.lookup(i).session.minFlowRate
for all $i \in \Sigma_{activeClients}$

[0024] The variable constraint bounds (i.e. the values to the right of the inequality symbol) of equations 1 - 4 and 6 are re-evaluated on a periodic basis (e.g. once per second) prior to the execution of the CAC procedure and optimizer. In

particular, the ***minFlowRate*** value starts out at the beginning of a session equal to the streaming rate. By construction the ***minFlowRate*** rate never exceeds this initial value so long as constraint 6 is honored. In fact, constraint 5 implies that the ***minflowRate*** value must be a diminishing function of time that may hold its value for a time but never rises. As seen from equation 6, the actual data rate of the channel, ***flowRate***, is always greater than or equal to the ***minFlowRate***. By design, and virtue of the fact the present invention uses faster-than-realtime transmissions, the system quickly gets ahead of itself and ensures that after initial conditions, the ***minFlowRate*** is always equal to or less than the real-time rate and that it continues to decrease. As we shall see, the CAC procedure exploits this monotonic characteristic of the minimum flow rate over time.

[0025] Constraints 2, 3 and 4 are of like kind, each specifying an upper bound on individual channel flows. Whereas the bound for constraint 2 is typically a constant, the bounds on 3 and 4 will vary over time. Nevertheless, only one of the three bounds is effective at any given time, namely the one with the smallest bound value, given by:

(7) client.lookup(i).session.maxFlowRate = minimum of

1) client.lookup(i).channel.maxFlowRate,

2) (client.lookup(i).channel.bufferSize - client.lookup(i).channel.bufferLevel)*

8/60 + client.lookup(i).session.mediaContent.averagePlayRate,

3) client.lookup(i).session.payloadToGo * 8/60

Consequently, formulas 2, 3, and 4 can be consolidated into a single constraint, the bound for which is computed at every scan to be the smallest bound of associated constraints 2, 3 and 4.

(8) client.lookup(i).channel.flowRate < = client.lookup(i).session.maxFlowRate,

whereby for all $\mathbf{i} \in \Sigma_{\text{activeClients}}$, maxflowRate is given by equation (7).

At any one time, individual channel flows are constrained over a range, as follows:

(9) client.lookup(i).session.flowRateRange = client.lookup(i).session.maxFlowRate - client.lookup(i).session.minimumFlowRate

Value Functions

[0026] The value functions introduced previously can be expressed mathematically as linear functions of channel flows, as follows:

Optimizing Throughput (Maximal Flow)

(10) value $= \Sigma_{\text{i} \in \text{SactiveClients}}$ client.lookup(i).channel.flowRate)

Optimizing Charges (Maximal Charges)

(11) value $= \Sigma_{\text{i} \in \text{SactiveClients}}$ (client.lookup(i).channel.flowRate * client.lookup(i).costOfService)

Optimization Problem Statement (Figure 3)

[0027] The optimization problem, which in one embodiment is strictly throughput and in another case is charge, can be stated simply as follows:

Find values for

client.lookup(i).channel.flowRate for all $i \in \Sigma_{activeClients}$

constrained by inequalities 1 through 5, such that the value obtained by evaluating expression 10 or 11 assumes a maximum.

[0028] Both of these problem formulations are examples of Linear Programming for which a number of well-known and generally effective computational solutions exist. In linear programming one seeks to optimize a linear cost function of variable **x**

(12) $c*x = c_1*x_1 + \ldots + c_n*x_n$

subject to a set of linear inequality constraints

(13) $A*x <= b$

where $x^T = (x_1,\ldots,x_n)$, $c = (c_1,\ldots,c_n)$ are the state variable & cost vectors, A is an n-by-m matrix, $b^T = (b_i,\ldots b_m)$ is the constraint vector, and the operator '*' stands for matrix or scalar multiplication.

[0029] Figure 3 is introduced as illustrative of the problem statement and the general methods of the prior art, and is not incorporated as an element of the invention.

[0030] The linear programming problem as well as its solution can best be understood with the aid of geometry. Figure 3, depicting a 2-dimensional Cartesian problem space, inequality constraints (13) define a convex hull H 310 over which a search for an optimum value of $\mathbf{x} = (x_1,x_2)$ is permitted to range. The cost vector **c** 350 defines an infinite family of equal cost lines (hyper-planes) which lie orthogonal to **c**. Three examples of such lines are shown in L_1 360, L_2 365, and L_3 370., each of progressively higher value. The supreme value of the cost function is obtained by sliding along **c** 350 till one can go no further, in this instance toward vertex V_4 340 of hull H 310. Many well-known methods (e.g. the Simplex Method) work roughly in this fashion, exploiting the fact that at least one optimum point must be at a vertex. In particular, the Simplex method algorithm begins by finding a vertex (e.g. V_2 320), and then moves along a sequence of vertices (e.g. V_3 330, V_4 340) improving itself each time until no further improvement is possible & the summit is reached.

[0031] Let us suppose instead that V_3 330 were placed along L_3 370 along with V_4 340. According to prior art methods, V_3 330 and V_4 340 are the two possible solutions, but the equally valuable points in between them are not. As we shall soon see, the problem of throughput optimization (6) falls in this category.

[0032] While vertex V_1 300 does not factor into this description, it is depicted in Figure 3 for completeness.

Flow Modulation

Methods for Maximal Flow

The following sections detail two embodiments to optimize total data flow.

Overview (Figure 4-a)

[0033] Figure 4-a depicts a scenario involving two flows. The convex hull is in this instance bounded by line segments L1, L2, L3, L4 and L5. L6 is a boundary used in a different embodiment, however the present embodiment uses L5 and not L6. Flow f_2 can range over the interval separating line segments L1 from L3, namely f_2^{MIN} and f_2^{MAX}; the range is depicted as f_2^{RANGE}. Flow f_1 can range over the interval between lines L2 and L4, namely f_1^{MIN} and f_1^{MAX}, and depicted as f_1^{RANGE}. The sum of flows f_1 and f_2 is constrained to lie inside of line segment L5 which, by construction, is always orthogonal to the cost vector $\mathbf{C_f}$. Cost vector $\mathbf{C_c}$ is also illustrated but used in a distinct embodiment. In the present embodiment only $\mathbf{C_f}$ is used. In the illustrated example of the present embodiment, the constraint on total flow is set to 5, and is therefore low enough to cause L5 to intersect L3 and L4. This would not have been true had the value chosen had been 10 instead of 5. With L5 safely out of contention, the convex hull would instead be a simple rectangle bounded by L1 through L4, thereby permitting both flows to assume their respective maxima without interference. In practice operational constraints exist intrinsically or are imposed from the outside so as to ensure cost effective sharing of potentially costly network resources.

[0034] Supposing Figure 4 to be correct, the well-known methods would select vertex $V_{3\text{-}5}$, which lies at the intersection of L3 and L5, or $V_{4\text{-}5}$, which lies at the intersection of L4 and L5. These solutions, though optimal, are undesirable for the present invention as they fail to spread available bandwidth over all channels as fairly as would a centrally located interior point of L5. For this reason, two alternative optimization methods are taught, which are adapted to the particular needs of this problem and ensure a fairer allocation of constrained bandwidth among all channels.

Iterative Procedure (Figure 5)

[0035] In order to optimize use of all available bandwidth, the following general method is used, with the details illustrated in Figure 5. This method is a solution for the problem illustrated in Figure 4-a, which geometrically illustrates the optimization problem in the limited case of two flows, f1 and f2. The following description expands the problem to an arbitrary number of clients (and therefore flows) and presents a method for solving this optimization problem.

[0036] Referring to Figure 5, in step 500, values are calculated for the ***session maxFlowRate*** and ***session.minFlowRate*** for each client as per the minimum and maximum constraint bound expressions in equations 6 and 8, respectively. This step correlates to the determination of $f_1$min, $f_1$max, $f_2$min and $f_2$max from Figure 4-a.

[0037] The difference between these two yields the ***session.flowRateRange*** of each client. Thus:

session.flowRateRange = session maxFlowRate- session.minimumFlowRate

[0038] In step 505, the active clients are sorted in an ascending fashion based upon their **session.*flowRateRange***. As will be shown this critical step facilitates allocation of the remaining server bandwidth as evenly as possible among all active channels, thus maximizing the number of channels that benefit by use of the total server bandwidth. An arbitrary assignment of remaining bandwidth is likely to saturate the server before all channels have been assigned extra bandwidth, thereby favoring certain channels on an ad-hoc basis. This step correlates to keeping the solution in bounds of the space delinated by line segments L1-L5 of Figure 4-a.

[0039] In step 510, each client's channel flow rate is set to the ***session mimimumFlowRate***.

[0040] By doing so, it is ensured that the minimum flow constraint is met for each session and that the minimum flow rate is a non-increasing function of time, which is critical to the proper functioning of the CAC procedure. This portion of the process also ensures that the solution, starting from the vertex in Figure 4-a as defined by the intersection of L1 and L2, moves generally in the direction of vector c_f . All clients are also marked as unprocessed.

[0041] In the next step, 520, ***server.flowRate*** is set to the sum of each active client's **session.flowRate.**

[0042] Next, the following is iterated over all clients in sorted sequence (during any given iteration the selected client is given by its ***id***) by performing steps 530 through 570. In step 530 evaluating the following expressions test for possible server saturation:

delta = (server.maxFlowRate - server.flowRate) / (qty of un-processed clients)
range = client.lookup(***id***).session.maxFlowRate -
client.lookup(***id***).session.flowRate

[0043] If ***range*** is greater then ***delta***, this implies that the server can be saturated in this iteration by allocating ***delta*** to all unprocessed clients (step 540).

[0044] On the other hand, the 'no' path for step 530 implies that the server is not saturated and that the present client (given by ***id***) will saturate first. Accordingly, in 550 the ***delta*** variable is set as follows:

delta = range

[0045] To again correlate this process back to the geometry of Figure 4-a, server saturation is indicated when the solution which is being sought in the direction of vector c_f goes beyond line segment L5.

[0046] Next, the flow rate is incremented for all unprocessed clients by ***delta***, causing client ***id*** to saturate.

[0047] In step 560 the server flow rate is adjusted accordingly:

server.flowRate = server.flowRate + delta * (qty of unprocessed clients)

In step 570 the client given by ***id***, now saturated, is marked as processed.

Algebraic Procedure (Figures 4-b and 15) By Interpolation

[0048] Referring to Figure 4-b, the iterative method described in the previous section begins its search for a maximum from vertex V_{min} along the direction shown by line C_1. In contrast, the present method follows the diagonal line segment L_{diag} of the rectangle bounded by lines L1 through L4, starting at vertex V_{min} and ending at point $V_{3\text{-}4}$.

[0049] Provided it exists, the intersection between L_{diag} and L5, indicated by V_f, is optimal on the same basis as any other point lying along the intersection of L5 with the rectangle bounded by L1 through L4, as previously discussed.

[0050] Whenever L5 does not intersect this rectangle, the optimal solution is given by vertex V3-4 at which f1 and f2 both assume their respective maxima.

[0051] In the first instance, the coordinates for point V_f can be obtained by elementary vector geometry and algebraic manipulation, as follows:

First, we define a number of abbreviations,

f_k^{min} represents client.lookup(k).session.minimum flow rate

f_k^{range} represents client.lookup(k).session.flow rate range

f_{svf}^{max} represents server.maxflowrate

We seek scale factor x such that the vector sum of $(f_1^{min} \ldots f_n^{min}) + x\ (f_1^{range} \ldots f_n^{range})$ intersects an equi-cost hyperplace for capacity c. The point of intersection is obtained by solving equation:

$$(f_1^{min} + \ldots + f_n^{min}) + x(f_1^{range} + \ldots + f_n^{range}) = c$$

Solving for x, we obtain:

$$x = [f_{svr}^{max} - (f_1^{min} + \ldots + f_n^{min})]/(f_1^{range} + \ldots + f_n^{range})$$

where $f_{svr}^{max} - (f_1^{min} + \ldots + f_n^{min})$ represents the unused bandwidth beyond the minimum allocation for each session. For any given session, the optimal flow rate is given by:

$$f_i = f_i^{min} + x\, f_i^{range}, \text{ if } x < 1,$$

or

$$f_i = f_i^{min} + f_i^{range}, \text{ if } x > 1$$

[0052] This solution by interpolation is interesting by virtue of the great efficiency of the calculation, and the fact that no session saturates ($x >= 1$) unless all sessions saturate. In contrast, the previous method entails considerably more computational effort, and tends to saturate sessions with the lowest reserve capacity.

[0053] A block diagram for this algorithm is depicted in Figure 15. Block 1500 establishes the maxim and minima for each flow. For each flow the minimum is subtracted from the maximum to obtain the range. Available Bandwidth is calculated in block 1520, as the difference between the aggregate flow capacity and the sum of flow minima. Factor x is calculated next in block 1540, and tested against 1 in block 1650. Flow rates for each session are computed in block 1560 if x is less than 1, or 1570 in the contrary case.

A Method for Maximal Charge

[0054] The following sections detail one embodiment to optimize the total monetary charges within the system. The second method is algebraic in nature, and thus very efficient.

Overview (Figure 4-a)

[0055] Referring back to Figure 4-a, cost vector C_c lies orthogonal to line L6, which intersects the convex hull at the vertex formed by the intersection of lines L4 and L5, namely V_{4-5}. This cost vector, and the optimal point that it implies, favors flow f1 over flow f2 . In this example, as the cost of service for f1 equals 2, thus exceeding the cost of service of 1 set for f2 . As the number of flows grow to exceed the number of distinct categories of service (and associated costs of service) the unique optimal solution, depicted in Figure 4 for the case where every flow has a distinct cost of service, no longer applies. Once again a plurality of flows within a service category vie for bandwidth which a method should endeavor to distribute evenly. This method is derived from the previous one, and optimizes one cost category after another, starting with the most costly and ending with the least costly, or when all available capacity is allocated.

An Iterative Search Procedure (Figure 6)

[0056] Let the service categories be denoted by k= 1...N, where k also denotes the cost of service.

[0057] Let $C_1..C_N$ be the partition of $S_{activeClients}$ that places all clients with cost of service k in set C_k. Partition sets C_k can be ordered to form sequence SeqC = $C_N...C_1$.

[0058] Figure 6 depicts the method for implementing the method to maximize the cost of service (service charge).

[0059] This method is nearly identical to the iterative procedure used to maximize flow. The principle difference stems from the partitioning of clients according to their category (cost) of service: clients charged most are allocated bandwidth preferentially. This is accomplished by adding another level of iteration around the method of Figure 5. The inner iteration (steps 650 through 680) functions exactly as before, with the difference that its actions are limited to the clients belonging to the given service category ***k*** (i.e. $C_{k)}$. This difference also holds true of step 640 which sorts category ***k*** clients according to their flow ranges prior to entry in the bandwidth-allocating inner loop. The outer loop proceeds down a sorted sequence of service categories SeqC (generated in step 630), starting with the category generating the greatest revenue to the service provider. Given a fairly static set of service categories, this sort need be performed only when the categories undergo change. Steps 670, 675 and 680 are identical to their counterparts in the method of Figure 5 (i.e. 570, 575 and 580).

[0060] The net effect of this method is preferential allocation of bandwidth according to category of service, and equitable treatment of clients within the same category of service.

An Iterative Algebraic Procedure (Figure 16)

[0061] The algebraic method used to maximize bandwidth (Figures 4b and 15) can be viewed as a special case of cost optimization in which all costs are equal. By construction, all sessions belonging to a given category, starting with the most expensive category, and ending with the least, and updating available bandwidth after each step in sequence, we obtain an iterative algebraic method that scales much better than the preceding method.

[0062] A block diagram for this algorithm is depicted in Figure 16. Block 1600 establishes the maxima and minima for each flow. For each flow, the minimum is subtracted from the maximum to obtain the range. In block 1610, every session flow is assigned the minimum allowed value, which value will apply by default should the iterative procedure run out of bandwidth before all categories can be considered. Block 1620 computes the initial value for available bandwidth, as the difference between the aggregate flow capacity and the sum of flow minima.

[0063] Flow values are obtained for each cost category in order of decreasing cost within blocks 1640 through 1675. Factor x is calculated next in block 1540, and tested against 1 in block 1650. Flow rates for each sessions of the category under consideration are computed in block 1660 if x is less than 1, or 1670 in the contrary case. In the former case there is no more bandwidth to allocated to the sessions in the category under consideration.

Call Acceptance Control (CAC)

CAC for Maximal Flow Overview (Figures 7-8)

[0064] The CAC procedure applicable to this flow optimization relies on the essential step of accepting a new client if and only if the added load induced thereby does not compromise service to existing clients or the new one. This critical step could not be accomplished without the close integration with previously- described flow-modulation methods of Figures 5, 6, 15 and 16.

[0065] According to the previous discussion, the minimum flow rate is the minimum sustained flow rate that guarantees that the associated viewer will not be subject to interruptions in service due to a shortfall of content from the media server. It follows that whenever data is being delivered at a rate in excess of the minimum flow rate, a downward adjustment toward the minimum level could be accommodated as needed to surrender bandwidth to any newcomer.

[0066] Figure 7 depicts content flow over a channel for the course of a typical session, and also how data is delivered under real-time streaming D. The amount of content delivered is the same in either case, but the manner of delivery differs considerably. A session is launched at time 0 as the network is lightly loaded, and the optimizer sets an accordingly high flow rate. Another client emerges at the end of interval 700, causing a downward adjustment to the flow rate over interval B, as available bandwidth is shared between two sessions. During both of these intervals the minimum flow rate 720 drops quickly, as data accumulates in the client's media buffers. At the end of interval B, a massive influx of clients necessitates that flow be dropped to the minimum flow rate, which now lies substantially below the streaming rate D and is held until all data is delivered at the end of interval C. Note that the minimum flow rate, shown as element 720, diminishes monotonically over time.

[0067] The ***server swing capacity*** is defined as the difference between the maximum capacity of the server and the total minimum flow rates for all active clients. Therefore:

(14) swingCapacity =

server.maxFlowRate - $\Sigma_{i \in SactiveClients}$ (client.lookup(i).session.minFlowRate)

[0068] Given the monotonic decreasing nature of session minimum flow rates, server swing capacity can readily be seen to be a *monotonic increasing* function of time over the intervals separating client admissions, at which point it undergoes a drop as a new load is taken on. This all-important characteristic implies the following:

Any client admitted for service based on the present value of swing capacity is guaranteed to have sufficient bandwidth at its disposal over the entire future course of the session.

[0069] Figure 8 depicts the server swing capacity 800 over the course of the sessions illustrated in Figure 7. Swing capacity rises quickly over intervals A & B as data is delivered at high flow rates over the network. It holds steady over interval C when all channels flow at their minimum rate then jumps at the end of C before resuming its monotonic rise once again.

Procedure (Figure 9)

[0070] In this procedure, which executes on a periodic basis, queued clients awaiting bandwidth are scanned in FIFO order. For each one, the required bandwidth is computed as per the client's prior content selection. If the available swing capacity (reduced by a safety margin) exceeds the amount required, then the client is activated and swing capacity is adjusted accordingly. Otherwise, two possible cases are considered: 1) under the *FirstFit* embodiment, the procedure

continues scanning clients to the end of the queue, activating clients whose requirements can be met; 2) under the *FIFO* embodiment, the procedure ends with the first candidate client whose requirements cannot be met.

[0071] In step 900, available server swing capacity is evaluated according to the formula

swingCapacity =

$$\text{server.maxFlowRate} - \Sigma_{i \in \text{SactiveClients}} (\text{client.get(i).session.minimumFlowRate})$$

The bandwidth requirement for client ***id*** in Step 920 is obtained as follows:

required_bandwidth = client.lookup(***id***).contentSelection.averagePlayRate

The predicate evaluated in Step 940 is given by the expression:

(required_bandwidth < = swingCapacity - server.cac_flowSafetyMargin)

[0072] In step 950, client activation entails allocation of a session and a channel, and insertion in the set of active clients eligible for bandwidth allocation by the optimal flow modulator.

[0073] In step 960 the swing capacity is diminished by the amount reserved for the activated client:

swingCapacity = swingCapacity - required_bandwidth;

<u>Responding to Variations in Network Capacity (Maximal Flow)</u>

[0074] In the CAC procedure for maximal flow, a safety margin was introduced, namely *server.cac_flowSafetyMargin*, to provide the means for ensuring that the server's swing capacity will never fall below a minimal threshold value.

[0075] According to this procedure, the following inequality always holds true:
(15) swingCapacity > = server.cac_flowSafetyMargin

[0076] In the previous discussion, a server's swing capacity provided the basis for determining whether or not a prospective client should be allocated bandwidth.

[0077] By holding *server.cac_flowSafetyMargin* in reserve, the CAC algorithm forces delivery of content at faster than real-time rates among accepted clients, even under the heaviest load. The net effect is to apply upward pressure on client side buffer levels, thus promoting continuous accumulation of content and a jitter-free viewing experience once a session is under way.

[0078] In another embodiment, server swing capacity can also be interpreted as specifying the *maximum* amount by which the *server.maxFlowRate* constraint can be dropped without affecting service, should such an adjustment prove necessary due, for instance, to an influx of exogenous network traffic that diminishes the amount available for multi-media services. Parameter *server.cac_flowSafetyMargin* can thus be set so as to *guarantee a minimum capacity to tighten the constraint on maximum server flow* in response to unexpected load changes that affect the server's ability to service its existing clients as well as new ones.

Anticipating Scheduled Variations in Network Capacity (Maximal Flow)

Overview (Figure 10)

[0079] Figure 10 depicts how the constraint on maximum flow might be allowed to vary according to the time of day, day of the week, and so forth, in expectation of time-varying traffic flow levels extrapolated from past experience, traffic flow models, etc. Maximum flow rate 1000 can be seen to vary based upon the time of

day. In practice, defining the right-hand-side of inequality constraint 1 as a time-dependent expression can impose such time-varying capacities. According to the previous description, the optimizer, which executes on a periodic basis, will automatically seek new flow levels for every active session as the constraint varies. There is, however, no guarantee that an acceptable operating point will be found for all sessions (i.e. one that respects the minimal and maximum constraints on session channel flow). One such example is the case where the server is loaded to the limit and total capacity is curtailed in excess of the aforementioned safety margin. Should such a situation arise the only recourse may well be the termination of a number of established sessions (i.e. load shedding).

[0080] The goal is to eliminate service disruptions of this sort by allowing the CAC procedure to look ahead into the future, and accept new clients only if these can be accommodated without any compromise in service in the midst of *previously anticipated changes* in available network capacity. The following CAC procedure generalizes the previous one: before accepting a client, the test on swing capacity is repeated over a sequence of time segments that cover the proposed viewing period.

Definitions -

Let:

(16) t_end(i) = client.lookup(i).session.playTimeToGo + t_now

Let server.maxFlowRate(t) be server flow capacity as a function of time, as exemplified in Figure 10.

[0081] Let Seq_T(t_now) = advancing sequence of future times, lead by t_now, when server.maxFlowRate(t) undergoes a step change. For instance, at 9:15 in Figure 10 this sequence reads as follows: 9:15, 9:30, 11:30, 13:30, 6:30, 7:30.

[0082] The server swing capacity at a future time t is computed according to the capacity and worst-case client flows at time t.

(17) swingCapacity(t) = server.maxFlowRate(t) -

$$\Sigma_{t_end(i) > t} \text{(client.lookup(i).session.minFlowRate)}$$

[0083] It is noteworthy that the worst-case client flows at time t are expressed in terms of the present minimum flow rates, which cannot increase over time, but might hold steady. Finally, a predicate is defined that tests whether a prospective customer will cause swing capacity to be exceeded at some time t, as follows:

```
(18) boolean client_fits(i ,t) {

        if(client.lookup(i).contentSelection.averagePlayRate <=

            swingCapacity(t) - server.cac_flowSafetyMargin)

        return true;

    else return false;
    }
```

Procedure (Figure 11)

[0084] This procedure is an adaptation of the first, which has been extended to consider swing capacity at times in the future when capacity undergoes scheduled changes. Before accepting a client, its minimal bandwidth requirement (which by construction of the flow modulator will never increase over time) is checked against *projected swing capacity* at points in time when total available capacity undergoes scheduled step changes, provided these times fall within the proposed content viewing period. A candidate is activated only if all tests succeed.

[0085] Step 1100 builds a sequence of time values (SeqT) at which step capacity changes are scheduled to occur. The first element of this sequence is t_now, representing the present.

[0086] Beyond step 1100 the queue of waiting clients is scanned in FIFO order, yielding a candidate designated by ***id*** at each iteration.

[0087] The bandwidth requirement for client ***id*** in Step 1120 is obtained as follows:

required_bandwidth = client.lookup(***id***).contentSelection.averagePlayRate

[0088] The worst-case end time for content flow to ***id*** is obtained according to the content selected, as follows:

t_end = t_now + client.lookup(***id***).selected.playTime

[0089] Steps 1130 through 1150 are executed within an iteration for each time point t in SeqT falling between t_now and t_end. This iteration is ended in step 1130 if t exceeds the time window of interest, or in step 1150 if the supply of scheduled capacity changes is exhausted.

[0090] For each time value, step 1140 compares required bandwidth to projected swing capacity.

Projected swing capacity at time t is:

$$\text{swingCapacity}(t) = \text{server.maxFlowRate}(t) - \Sigma_{t_end(i) > t} (\text{client.lookup}(i).\text{session.minimumFlowRate})$$

[0091] Note that only active clients whose t_end times occur after t are considered in the sum of minimum flow rates.

[0092] The predicate expression used in step 1140 at time t is thus:

(required_bandwidth < = swingCapacity(t) - server.cac_flowSafetyMargin)

Step 1160 performs the same actions as step 660 in the previous CAC flowchart

[0093] The first CAC process is a special case of the present one, in which the set of step change times to server.maxFlowRate is empty (i.e. server.maxFlowRate is constant), and $Seq_T(t_now) == t_now$.

[0094] In preparing Seq_T(t_now), one need only consider future times that will pass before the longest possible content is played out if started at t_now. In order to sidestep problems associated with rollover (at midnight, year 2000, etc.), time is best expressed as a monotonically increasing value (e.g. seconds since Jan 1 1990).

CAC for Maximal Charges

Overview (Figure 13)

[0095] Previously, a method for flow modulation was presented that maximizes charges to clients with active sessions. The CAC embodiment presented previously was not sufficient as it does not consider the cost of service as a basis for connection acceptance. As a result, it may turn away higher paying customers while granting service to lower paying ones, thereby defeating the purpose for this particular embodiment. Therefore, another embodiment is defined which offers the following features:

1. Awaiting clients are serviced in order of their respective service categories, higher paying clients first.

2. Once accepted, a client is guaranteed to receive acceptable service irrespective of its service category.

3. Under heavy load conditions higher paying customers are more likely to be accepted than lower paying ones.

4. Lower paying customers will no be starved for service when higher paying ones enjoy a surplus.

5. Available bandwidth is not thrown away needlessly while clients are being denied service.

[0096] The first objective is easily met by dividing the client queue into as many bands as there are service categories, resulting in a banded queue. Bands are ordered within the queue according to their service categories, with the costliest category in front. As prospective clients arrive and make their selection they are placed in their respective queue band according to their service category (which may be set contractually, according to content selection, etc.).

[0097] Our second objective is met by employing a procedure patterned after those presented previously & offering the same guarantee. Toward our third and fourth objectives we propose dividing total available bandwidth in as many strata as there are service categories. As depicted in Figure 12, two service categories are shown, Premium and Basic, each entailing an associated cost of service. A prospective client is accepted only if there is sufficient swing capacity available within its given service category. The swing capacity for a given category is given by the smaller of 1) the difference between its maximum floor flow rate (corresponding to the top of the stratum for the service category) and the sum of the minimum rates of all active sessions in its category or below, and 2) available swing capacity overall. Finally, our fifth objective is met by allowing the flow optimizer to function freely subject to its operational constraints. The imposed ceilings on call acceptance by category relate to *minimum flow rates*, which merely impose a floor on *actual flow rates*. For example, basic clients might well consume all available bandwidth 300 in the absence of any premium customers, yet could be throttled back toward their floor flow rates (which together cannot exceed 200 in this example) at any time should any premium customer suddenly demand service. In contrast, premium customers could consume the entire 300

bandwidth. As lower paying customers appear these would be admitted to the degree that their quota on minimum flow is not exceeded (i.e. 200) and the availability of swing capacity on the system.

Procedure (Figure 13)

[0098] The present procedure requires a number of ancillary definitions, which follow:

Let the service categories be denoted by k= 1...N, where k also denotes the cost of service.

Let server.maxMinFlowRate[k-1] be the top of the stratum for service category k. Note that server.maxMinFlowRate [N-1] = server.maxFlowRate.

Let S_K be the set of active client indices with a service category *equal to or less than* k. Note that S1 is contained in S2, S2 is contained in S3, and so forth, and that $S_N = S_{activeClients}$.

Let swingCapacity(k) denote available swing capacity for service category k. By construction:

(19) swingCapacity(k) = minimum of:
(server. maxMinFlowRate [k-1] - $\Sigma_{i \in Sk}$(client.lookup(i).session.minFlowRate)),
(server.maxFlowRate - $\Sigma_{i \in SactiveClients}$ (client.lookup(i).session.minFlowRate)))

[0099] Referring to Figure 13, this method is used for CAC when multiple rate tariffs are in effect, and there is a desire to maximize economic returns to the service provider while offering acceptable service to all.

[00100] All waiting clients are scanned in FIFO sequence. The actions taken in Steps 1320 and 1360 are identical to those described in connection with earlier CAC flowcharts.

[00101] Step 1340 evaluates a predicate expression that tests whether the required bandwidth can be accommodated without exceeding the lesser of 1) swing capacity available to the client's category of service, and 2) total available swing across all categories of service. The latter factor could be determinative if all available bandwidth were allocated to high paying customers, leaving lower paying ones such as the proposed client unable to draw from their unfilled quota.

Let us suppose that candidate client ***id*** belongs to rate category ***k***.

We define the swing capacity available in rate category ***k*** as:

swingCapacity(***k***) = least of:

(server.maxMinFlowRate[k-1] - $\Sigma_{i \text{ in } Sk}$ (client.lookup(i).session.minimumFlowRate))

and

(server.maxFlowRate - $\Sigma_{i \in SactiveClients}$ (client.lookup(i).session.minimumFlowRate))

The predicate expression invoked by step 1340 can now be written as follows:

(required_bandwidth < = swingCapacity(***k***) - server.cac_flowSafetyMargin)

[00102] This algorithm processes queued clients in band sequence, and within every band in FIFO order. If the predicate evaluates to true, the client is activated. Otherwise two possible cases are considered: 1) under the *FirstFit* embodiment, the procedure continues scanning clients to the end of the banded queue, activating clients whose requirements can be met; 2) under the *FIFO* embodiment, the procedure ends with the first candidate client whose requirements cannot be met. Many other variations on these two embodiments might also be considered.

Anticipating Scheduled Variations in Network Capacity (Maximal Charge)

Overview

[00103] The procedure applicable to optimization of delivery charges is obtained by blending elements of the CAC method depicted in Figure 13 into the method depicted in Figure 11, which applies without change. To understand how this might work it may be useful to visualize a version of Figure 10 stratified along its length in the manner of Figure 8. As the maximum flow level undergoes a step change, so too do the widths of its constituent strata in equal proportion.

Procedure

[00104] As previously mentioned, the CAC method (Figure 11) applies to this circumstance also, provided we alter the definition of two routines, (17) and (18), upon which that procedure relies, yielding (20) and (21), and adopt the banded queue organization outlined in the previous section.

[00105] The server swing capacity at a future time t is computed according to the capacity and worst-case client flows at time t.

(20) swingCapacity(k, t) = minimum of (

(server.maxFlowRate(t) * (server.maxMinFlowRate[k-1] /server.maxMinFlowRate[N-1])

$\Sigma_{i \in Sk \,\&\, (t_end(i) > t)}$ (client.lookup(i).session.minFlowRate)),

(server.maxFlowRate - $\Sigma_{i \in SactiveClients \,\&\, (t_end(i) > t)}$ (client.lookup(i).session.minFlowRate)))

Finally, we define a predicate that tests whether a prospective customer will cause swing capacity to be exceeded at some time t, as follows:

```
(21) boolean client_fits(i ,t) {
        k = client.lookup(i).costOfService;
        if(client.lookup(i).contentSelection.averagePlayRate <=
                        swingCapacity(k,t) - server.cac_flowSafetyMargin)
                return true;
        else return false;
    }
```

System Description

[00106] Referring to Figure 14, a block diagram illustrating a preferred embodiment for a system implementing the methods presented herein is shown.

[00107] Block 1485 depicts plurality of network-based client computers that receive data from a server over the course of a session. Every client sessions has an associated session block 1435 within the server by means which a flow rate of content from client to server is effected and regulated to a given flow rate set-point. The flow optimizer 1430 manages bandwidth utilization across all sessions that have been admitted by the system call admission control (CAC) and the bandwidth call admission control blocks, labeled 1400 and 1420 respectively. Specifically, the flow optimizer 1430 modulates the flow rate set-point of every active session so as to optimize aggregate flow or, more generally, cost.

Call Admission Control

[00108] Whenever a client contacts a server requesting service, the server must determine whether or not to admit the client. This admission function is performed in two separate phases. The system call admission control block 1400 considers whether or not sufficient internal resources exist to support the request.

Toward this end, the system CAC 1400 estimates the needs of the prospective client with respect to a set of limited system resources such as I/O bandwidth, cache memory, open files, threads, etc. A request is denied if any required resource cannot be obtained. In the contrary case, the request is passed on to the Bandwidth CAC, which tests if the client fits and admits or rejects the client accordingly. The swing capacity is computed by the flow optimizer 1430 on a periodic basis according to equations (14) and (17) as appropriate. The managed bandwidth must reflect the true capacity of the attached network and the adapters leading thereto. This parameter should not be set arbitrarily high to prevent rejection of client requests. Doing so will cause the system to admit calls that cannot be properly handled, thereby diminishing the quality of the viewing experience.

[**00109**] Having admitted a client, block 1430 creates a client session block 1435, which then begins to converse with its client-resident counterpart, 1480) during their launch phase. Thereafter, the flow optimizer 1430 assumes control, and modulates flow over the session until either all content is delivered, or a failure to deliver is detected, or one of a number of VCR-like stream control events intervene (e.g. pause, rewind, fast-forward).

Server and Client Session Control Blocks

[**00110**] Data Transport Channel 1450 is responsible for transporting data packets originating from the flow regulator 1440 within the server to the former's peer entity 1460 within the client. The mode of communication between the peer entities may be connection-oriented (e.g. TCP, which delivers a byte stream in order, without duplication or loss) or datagram-oriented (e.g. UDP). Best-efforts datagram service is typically enhanced with acknowledgements to facilitate rapid recovery from occasional packet loss, out-of-sequence delivery, and duplication.

[00111] Peered session control channels 1445 and 1465 permit configuration and status data, together with miscellaneous commands, to be sent from client to server and vice-versa. A reliable connection-oriented transport service is typically employed for this purpose (e.g. TCP). Data and commands alike are multiplexed over this channel in the service of other entities within the clients or server. Thus, a datagram-oriented data transport channel 1460 within a client 1485 might employ the session control channel to ferry selective acknowledgements to its peer in the server. Similarly, the flow meter 1465 within the client 1485 forwards the measured flow rate to the associated flow regulator 1440 within the server.

[00112] The flow regulator 1440 obtains content data from a cache or disk, at the current offset into the content file, which it forwards as packets to the data transfer channel 1450. The size and/or pacing of the packets are determined by the flow regulator 1440 in order to achieve the flow rate set-point imposed by the flow optimizer 1430. The flow regulator 1440 is also responsible for determining the channel flow capacity to the client, which is the least of a configured value obtained from the client and a measured value. Toward this end, during the launch phase, the flow regulator 1440 might send content data packets to the client flow meter 1475 in a series of packet trains at progressively higher peak flow rates ending with the configured maximum flow rate, if any. The highest measured flow rate reported by the client flow meter 1475 is accepted as the flow rate capacity, which is posted for use by the flow optimizer 1430. Subsequently, the flow regulator 1440 will compare the flow rate set-point with the flow rates reported by the flow meter 1465, and down grade capacity as needed should the measured flow rate fall consistently fall below the requested flow rate. Whenever such a downgrading occurs, the flow regulator 1440 will test for subsequent

relaxation of a transient constriction by means of the aforementioned series of packet trains in which the peak packet flow rate exceeds the delivered flow rate.

[00113] The buffer manager 1470 accepts data from the flow meter 1465, which data is retained until it is consumed or passed over the content consumer 1480. The buffer will typically be implemented as a ring buffer in memory or on disk. The write cursor will lag the read cursor by a no less than a specifiable time interval so as to permit rewinds of acceptable scope without requiring selective data re-retrieval from the server.

Flow Optimizer 1430

[00114] The flow optimizer 1430 assumes control over a session once it has been launched, and its channel capacity has been determined. Subsequently, it modulates the flow rate set-point of every session such as to optimize aggregate flow or charges across all active sessions, subject to a variety of min/max constraints on sessions flows, and a maximum constraint on aggregate session flow, as previously discussed.

[00115] The flow optimizer 1430 continues to modulate session flow until all content has been delivered, or one of a number of session anomalies intervene, as follows:

[00116] A downgraded session flow capacity drops below the minimum session flow rate. The session is dropped by the optimizer 1430 as a solution involving this channel does not exist. The user is forced to apply for re-admission, with the option of accepting slower than real-time delivery at the present encoding rate, or accepting a degraded viewing experience at a reduced encoding rate better adapted to the presently available bandwidth.

[00117] A pause VCR command is received from the client. Flow to the client can continue until the client-side buffer is topped off, after which time flow drops to zero. The session is permanently dropped should the pause persists too long. Until that time, the CAC safety margin is temporarily increased by the jit (Just-In-Time) flow rate of the paused session. In this way the session can be resumed without the need for re-admission and the jit bandwidth is made available to currently sessions so long as the pause persists.

[00118] A VCR Jump-Forward command is received from the client. This action is problematic as it causes the just-in-time flow rate (calculated at the new forward offset) to increase, in violation of the assumptions of the CAC algorithm. It must be noted that this violation will occur even if the content that is sought has already been delivered to the client-side buffer. One workable policy is to force the client to apply for re-admission at the forward offset and with a suitably modified buffer level.

[00119] A VCR Jump-Backward (Rewind) command is received. This action may entail the need for re-transmission of content, as previously discussed. The just-in-time flow rate will decrease as per the new position and adjusted buffer contents.

Tunable Minimum Constraint

[00120] A parameterized family of minimum flow constraints can be defined as follows:

(22)

wherein: $f_k(t)$ = Target content flow rate for session k;

$f_k^{JIT}(t)$ = Just-in-time flow rate for session k;

(RHS of Equation (5))

β = Burst tuning factor (positive or zero); and

$f_k^{min}(t)$ = Minimum (reserved) flow rate for session k.

[00121] This family converges on $f_k(t) >= f_k^{JIT}(t)$ when β approaches 0. A β value of .1, for example, ensures a minimum flow rate that exceeds the JIT flow rate by 10%. Thus, non-zero values of β force early delivery of content to a player's media buffer, with beneficial effects on the viewing experience.

Alternative Call Admission Control

[00122] The traditional CAC algorithm compares the flow rate requirement of a prospective client with the unused bandwidth (obtained by subtracting the aggregate flow target from the server flow capacity) and grants service if unused bandwidth is not exceeded. This procedure may break down as the optimizer causes all available bandwidth to be used if it can, thereby reducing unused bandwidth to zero in the best case, even when a new client could be accommodated with a healthy margin to spare.

[00123] Nevertheless, a simple variation on this idea can be used. Available bandwidths can be defined as the difference between server flow capacity and the sum of minimum flow rates for each session computed according to (22) as follows:

(23) $f_{available} = f_{Svr}^{max} - (f_1^{min} + \ldots + f_n^{min})$

wherein: $f_{available}$ = Available bandwidth

f_{Svr}^{max} = Server aggregate flow capacity; and

f_n^{min} = Minimum (reserved) flow rate for session n.

[00124] Service is granted if the computed minimum flow rate of the prospective client is less than available bandwidth even when unused bandwidth is zero.

Toward a Tunable QOS

[00125] In the preceding discussion it is assumed that all clients share the same value of β. One might also consider a scheme whereby a client receives a β value according to the class/cost of service that client has signed up for: the greater the cost (and expected quality of service, or QOS) the greater the value of β.

[00126] Instead of maximizing charges by the methods described above, a variation on the algorithm to maximize flow is considered whereby the reserve flow computation for every session takes into account the individual β value of the associated client. In this fashion a single algorithm can serve either end. The optimizer first ensures that every session receives its required minimum bandwidth (which would now typically depend on β and elapsed session time) before allocating any excess bandwidth more or less evenly to all by interpolation. (According to Figure 15.)

[00127] The scheme is simpler computationally than the iterative interpolation method shown in Figure 16; it is also arguably more fair and stable with respect tot he allocation of available bandwidth.

Deadline-Driven Content Distribution

[00128] In delivering viewable or audible content to a player, the optimization algorithm imposes a minimum flow rate that ensures that all content is delivered by the implied deadline, which is the last moment of a play session. Notwithstanding, the optimizer attempts to deliver content earlier according to bandwidth availability within the server taken as a whole. A similar, though far simpler scenario arises relative to the distribution of content from an optimized server to a target device, whenever the delivery must be accomplished by a designated time, or equivalently, within a given elapsed time, and when overlapped non-blocking consumption of the content at a fixed rate is not required.

[00129] One example concerns the application where a session bundle comprises a session associated with the featured program together with sessions for every advertisement scheduled to interrupt the feature program at a designated time. Each session is endowed with a separate media buffer, which, in the case of ads, would typically be large enough to accommodate the ad in full, thereby permitting a seamless transition to the ad at the appointed time.

[00130] In adapting the optimizer to the needs of content distribution we must revisit the formulation of the flow constraints, as follows:

1. Media buffers are not of a concern, let alone buffer overflow, and it can be assumed that all content received is saved away in a file on disk, or in memory awaiting further use.

2. For these same reasons, the value of β may be zero, at which the minimum flow rate equals the just-in-time rate obtained by dividing the content as yet undelivered by the time till deadline:

(24) $f_k^{JIT}(t_k) = L_k^{TOGO} / (T_k - t_k)$

wherein: L_k^{TOGO} = Content to go for session k, i.e., as yet undelivered by the server at time t, (client.lookup (k).session.payloadToGo).

Given the arbitrary format of the file to be distributed, T no longer signifies the "duration of play" at the average play rate (averagePlayRate); rather, T represents the elapsed time to the deadline measured at the moment the delivery session was launched, and t represents the elapsed time since session launch.

Session Bundles

[00131] A session bundle is a set of sessions that flow along a shared channel, and are thus subject to an aggregate flow constraint equal to the capacity of the shared channel. One important application of session bundles is connected with ad insertion.

[00132] It is not enough to treat each of the constituent sessions as independent with respect to the flow optimizer, for this practice might well result in session flow targets that do not exceed channel capacity when considered singly, yet exceed this same shared capacity when summed together.

[00133] A solution to this problem involves two distinct steps:

1. The sessions bundle is treated as a virtual session by the server optimizer, subject to the minimum flow constraint obtained by summation of the individual session minima, and a maximum constraint that is the least of (a) the sum of the least of constraints (3) and (4) for each session, and (b) the shared

channel capacity client.lookup(k).channel.maxFlowRate (f_k^{cap}). The flow optimizer then generates an aggregate flow target for all channels virtual sessions by interpolation, using:

(25) $Cost(t) = f_1(t) + .. + f_n(t)$

[00134] The cost vector in this instance is the n-dimensional unit vector, where n is the number of active clients.

(26) $c = (1, 1, ..., 1)$

[00135] Now it is possible to have an achievable aggregate flow target for the session bundle k that we must apportion optimally among the constituent sessions. Fortunately for us, our interpolation procedure of Figure 15 can be applied again to the sessions in our bundle, but where the aggregate flow target generated above replaces the aggregate flow constraint f_{svr}^{max}

Specifically:

For every flow f_{ki}, within session bundle k, the optimal flow rate is obtained by interpolation between minimum and maximum session flows:

(27) $f_{ki}^{opt} = f_{ki}^{min} + \alpha * (f_{ki}^{max} - f_{ki}^{min})$

(28) $\alpha = [(f_K^{bundle} - f_{k1}^{min} + \ldots f_{kn}^{min})]/[(f_{k1}^{max} - f_{k2}^{min}) + + (F_{kn}^{max} - f_{kn}^{min})]$

and the value of f_k^{bundle} is obtained from a higher level optimization in which session bundle k is treated as a virtual session for which:

(29) $f_k^{min} = f_{k1}^{min} + \ldots + f_{kn}^{min}$

(30) $f_k^{max} = \min(f_{k1}^{max} + .. + f_{kn}^{max}, f_k^{cap})$

It must be noted that session bundles are typically dynamic in nature, outliving many if not all of their constituent sessions. Before a session is added to the bundle two CAC decisions must be reached:

(1) establish bandwidth availability within the bundle; and

(2) bandwidth availability within the server.

Relationship to Adaptive Rate Control

[**00136**] The flow optimization methods should be viewed as constituting the lowest and perhaps only the first of many supervisory control layers to sit astride all streaming sessions, which comprise their own hierarchical stack of control functions; rate adaptive control sitting above a flow rate regulator which relies on a transport entity.

[**00137**] Channel capacity is known to vary widely over time. A capacity drop to below the minimum reserve flow rate is problematic as it causes the latter to rise in violation of its monotonicity assumption. In a server with available bandwidth to spare such a rise can be accommodated by the flow optimizer (by bumping the session's minimum flow reservation to the higher value) provided the flow deficit can be made up in the near term by draining pre-delivered content from the media buffer. Should either of these resources approach depletion, stream degradation to a lesser bit-rate or frame rate may be the only viable option short of a pause. Whether up or down, any rate change is a change to *fe*, which must be preceded by change to session's reserve flow rate allocation by the optimizer.

[**00138**] As can be seen, the optimizer and rate adapter must be integrated with care. One possible approach would be to modify a rate adapter such that it renegotiates its proposed *fe* value with the flow optimizer prior to effecting the rate change it deems appropriate based on information provided by the flow regulator. Rate increases might well be subject to deferral under heavy load conditions, awaiting bandwidth availability. The opposite is true of rate flow decreases: these would be forestalled as long as possible by the optimizer on a system that is not fully loaded, as previously discussed.

Live Events

[00139] Referring to Figure 17, the method of the present application can be extended to the optimization of "live", time-shifted "near-live" events, and cascaded delivery, wherein one server delivers content to another while the latter accepts clients for the same content. The extension assumes the following characteristics of the server and the live performance:

1. The performance is of a fixed duration T known in advance, encoded at an average rate *fe*, with a projected content payload of *fe*T*;

2. The origin server at the point of injection delays the stream by a small dwell time T^{DWELL} on the order of seconds (e.g. 10). Notwithstanding, the delayed content is available for early delivery to mirrored servers and players with the aim of providing these with a modicum of isolation from network jitter affecting the timely delivery of the live video frames.

3. Throughout the live event, captured content is stored in a file, thereby permitting late joiners to view the "live event" starting from any point between the present and the event start time;

4. At the conclusion of the live event, the encoded content, now fully captured to a file, is available for viewing over the balance of the admission window (e.g., 60 minutes in Figure 17).

[00140] The optimisation of live events and video on demand (VOD) differ principally in one respect, namely in the formulation of the server content underflow constraint.

For VOD, this constraint is

(31)

$L_k^{TOGO}(t)$ is initialised to the content size (*fe*T*) at that start of play, and decremented as content is delivered to the client. Δt is the time interval between successive periodic optimizations (e.g. 1 second). In practice this constraint rides

well above other operative maximum flow constraints (e.g. buffer overflow, channel capacity) until the very last calculation of the session flow target by the optimiser.

[00141] For a live stream, this constraint must additionally reflect the fact that content is streaming into the server (where it builds up), even as the server streams it out toward clients, and that the latter activity cannot possibly overtake the former.

[00142] Referring to Figure 17, (which illustrates how optimised live streams behave) line L1 depicts the build-up of freshly captured content to the server. Line L2, which is delayed (time-shifted) relative to L1 by the dwell time T^{DWELL}, represents the live performance as cast and viewable by clients. One such client is admitted at time A and joins the live session at the live moment B. The dashed curved line linking points B and C shows a plausible build-up of content in the client's media buffer in advance of play, as the viewer continues its advance along line L2. Past point C the top of the media buffer tracks the live capture stream and thenceforth advances along line L1. In this instance, the time shift between the live performance as cast (L2) and the live performance as captured (L1) imposes a maximum on the amount of content that could ever accumulate in a client media buffer, irrespective of its actual capacity.

[00143] Another client, admitted at time $t=10$, is interested in viewing the live stream from the beginning without missing anything. As before, the dashed line joining 10 and D depicts a plausible build-up of content in the client's media buffer in advance of play, as the viewer continues its advance along line L3, which is time-shifted by $(10+T^{DWELL})$ minutes relative to L1. The greater time shift (now between L1 and L3) permits more extensive pre-buffering of "near live" content.

[00144] The present constraints do not impose suitable flow limits at and beyond points C and D when the client delivery streams finally links up with the live capture stream, in the live moment. Consequently the optimiser may propose flow targets that cannot be realized.

[00145] Accordingly, the following modification for use in connection with live or cascaded streams is made:

(32) $f_k(t) <= [(L_k^{TOGO}(t) - \text{Live}^{TOGO}(t)] / \Delta t$

for a live event delivered at flow rate *fe*, we have

(33) $\text{Live}^{TOGO}(t) = \max(fe*(T-T^{DWELL}-t),0)$

[00146] $\text{Live}^{TOGO}(t)$ is the span between projected content size *fe* *T (level line L0 in Figure 17) and the content capture level line L1, whereas $L_k^{TOGO}(t)$ is the gap between L0 (i.e., *fe* * *T*) and the dashed curved line representing the content level delivered to the media buffer. The latter must always exceed the former. As the two approach one another this constraint takes effect, causing $L_k^{TOGO}(t)$ to always exceed $\text{Live}^{TOGO}(t)$ as it decreases at rate *fe*.

[00147] Viewers joining late and willing to see the live performance with some delay relative to the live case enjoy higher potential levels of isolation from network disturbances, and thus QOS, by virtue of their greater effective buffer capacity. By the same token, such viewers afford the optimizer greater latitude to optimize the flow of VOD and "live" content across load fluctuations, thereby enhancing server capacity. Viewers that wish to experience the live event in "real-time" nevertheless benefit by a modestly enhanced QOS conferred by a dwell time's worth of content in their buffers.

Summary

[00148] A method and system for call/connection acceptance and flow modulation for network delivery of video/audio programming is thus provided. Although several embodiments have been illustrated and described, it will be apparent to those skilled in the art that various changes and modifications may be made without departing from the spirit of the invention or the scope of the claims.

CLAIMS:

1. A method of bandwidth allocation for delivery of stored digital content from at least one server device to at least one client device by way of a network, the method comprising the steps of:

a) prescribing a control variable which represents a target flow rate from the server device to each client device;

b) determining time-varying constraints on the flow rate of the content;

c) determining a cost function of the control variables for all clients; and

d) prescribing bandwidth to all clients based upon the value of the control variables that maximize the cost function.

2. The method of Claim 1 wherein step (d) comprises performing periodic computations to update the value of the control variable such that the bandwidth can be continuously allocated to each client.

3. The method of Claim 2 wherein a new client is accepted by:

i) determining an admission capacity of the bandwidth;

ii) admitting a prospective client if the clients minimum allowed value of the control variable is less than the admission capacity; and

iii) wherein a client admitted for service is guaranteed to have sufficient content flow over the entire session.

4. The method of Claim 3 wherein:

The admission capacity equals a server swing capacity reduced by a predetermined safety margin which may be zero, the swing capacity equaling the difference between the server flow capacity and the sum of the minimum allowed flow rate for all clients.

5. The method of Claim 4 wherein the minimum allowed value of the control variable is initialized to the average consumption rate.

6. The method of Claim 4 wherein the minimum allowed value of the control variable is initialized to the average consumption rate multiplied by a factor greater than one.

7. The method of Claim 4 wherein the server flow capacity varies in a step-wise function over time according to a predetermined schedule and the method of accepting a new client further comprises:

i) determining a sequence of future step changes of server flow capacity;

ii) determining at each time in the sequence of future step changes the value for a future worst swing case capacity, the worst case swing capacity being obtained from the server flow capacity at the time by subtracting an extrapolated present minimum allowed flow rate for all active clients that are potentially active in the future;

iii) admitting a prospective client if a minimum allowed value of the control variable is less than the capacity obtained from the sequence and the present capacity;

iv) whereby a new client can be admitted without compromising the service to existing clients in the presence of previously scheduled server flow capacity changes and all clients accumulate content in their buffers to the extent of their respective buffer capacity.

8. The method according to Claim 7 wherein the method of accepting a new client further comprises:

i) partitioning the available bandwidth into partitions representing a prescribed service charge;

ii) determining a maximum-minimum capacity for a service charge to be the maximum allowed sum of all minimum allowed flow rates for all clients incurring an equal or lesser service charge, the maximum-minimum capacity equaling the sum of bandwidth allocations for all service charges less than or equal to the service charge;

iii) determinating a service-charge-specific swing capacity for a given service charge as the difference between the maximum-minimum capacity for the service charge and the sum of all minimum allowed flow rates for all clients incurring the service charge or a lesser service charge;

iv) determining the server swing capacity to be the server flow capacity minus a margin and minus the sum of the minimum allowed flow rate for all clients; and

v) determining the service-charge-specific capacity to be the least of the server swing capacity and the charge specific swing capacity.

9. The method of Claim 8 wherein the method of accepting a new client further comprises:

i) determining the sequence of future times of step changes to server flow capacity over a proposed consumption period;

ii) determining for each time in the sequence of future times, the future worst-case value for the service-charge-specific capacity, the worst case value being obtained by using the extrapolated present minimum allowed flow rate of all presently active clients that are potentially active at the time in the future; and

iii) admitting a client incurring a given service charge if the minimum flow rate of the client is less than the capacity obtained from the sequence and the present service-charge-specific capacity.

10. The method of Claim 3 wherein step (b) comprises determining time-varying constraints wherein:

i) an aggregate flow rate for all clients does not exceed a predetermined server flow capacity;

ii) the flow rate from the server to the client does not exceed a maximum allowed flow rate for the client;

iii) the flow rate to the client will never cause a buffer of the client to overflow;

iv) the flow rate to the client stops when the content is exhausted; and

v) the flow rate from the sever will never be less than the client's minimum allowed flow rate which may vary over time and may be zero.

11. The method of Claim 10 wherein the maximum allowed flow rate to the client is given by the minimum of one selected from the following:

i) a client flow rate ceiling;

ii) the flow rate required to fill the client buffer before the next periodic computation; and

iii) the flow rate required to complete the delivery of the content before the next periodic computation.

12. The method of Claim 11 wherein:

i) the minimum allowed client flow rate cannot increase over time, but may decrease such that the initial value of the control rate is no less than the average consumption rate;

ii) the control variable for the client is always greater than or equal to the current minimum allowed client flow rate; and

iii) the client buffer will never underflow until the content is fully consumed at the average consumption rate.

13. The method of Claim 12 wherein the minimum client flow rate is the product of the constant content flow rate from the client to the server that causes the last piece of content to be delivered at the last possible moment as the client buffer is being drained at the average consumption rate, with a factor greater or equal to one.

14. The method of Claim 13 wherein the minimum client flow rate is initialized to the average consumption rate.

15. The method of Claim 13 wherein the minimum client flow rate is initialized to the average consumption rate multiplied by a factor greater than one.

16. The method of Claim 13 further comprising the step of calculating the minimum client flow rate periodically.

17. The method of Claim 1 wherein the cost function represents an aggregate flow rate and is the sum of the flow rates for all clients.

18. The method of Claim 1 wherein the cost function represents a service charge and is the sum of the client flow rates multiplied by the client's cost of service.

19. The method of Claim 18 wherein:

step (a) comprises:

i) determining a maximum allowed flow rate and a minimum allowed flow rate for each client;

ii) determining a flow rate range for each client as the difference between the maximum allowed flow rate and the minimum allowed flow rate; and

iii) initializing a current flow rate for each client as the minimum allowed flow rate and summing the flow rate into the total server flow rate; and

step (d) comprises:

i) computing remaining server bandwidth as the difference between the maximum server flow capacity and the total server flow rate; and

ii) allocating remaining server bandwidth to remaining clients wherein all clients with a given cost of service receive bandwidth equally to the extent of their respective ranges, and no client with a given cost of service being allocated bandwidth unless all clients with a higher cost of service have received their maximum possible allocation of bandwidth.

20. The method of Claim 17 wherein step (a) prescribing the control variable comprises:

i) forming a hyperplane of control variables that aggregate to the maximum allowed aggregate flow rate;

ii) computing a first vector of minimum allowed client flow rates;

iii) computing a second vector of maximum allowed client flow rates;

iv) determining a multi-dimensional shape of which an interior diagonal spans the first and second vectors; and

v) finding a solution of control variables at the point of intersection between the diagonal and the hyperplane.

21. The method of Claim 20 wherein step (v) comprises finding a solution of control variables at the second vector if there is no point of intersection between the diagonal and the hyperplane.

22. The method of Claim 17 wherein step (a) comprises:

i) computing the sum of the minimum allowed flow rates to all active clients;

ii) computing the sum of the flow rate ranges for all active clients;

iii) computing the difference between the maximum allowed aggregate flow rate and the sum of the minimum;

iv) computing a factor as the ratio of the difference over the sum of the ranges;

v) if the factor exceeds 1, the control variable is set to the maximum allowed client flow rate; and

vi) if the factor is less than 1, computing the control variable by multiplying the client range by the factor and then adding the result to the minimum allowed client flow rate.

23. The method of Claim 17 wherein:

step (a) comprises:

i) determining the maximum allowed flow rate and minimum allowed flow rate for each client;

ii) determining the flow rate range for each client as the difference between the maximum flow rate and the minimum flow rate; and

iii) initializing the control variable for each client as said minimum allowed flow rate and summing the flow rate into a total server flow rate; and

step (d) comprises:

i) computing remaining server bandwidth as the difference between the maximum server flow capacity and the total server flow rate; and

ii) allocating remaining server bandwidth to remaining clients to the extent of their respective ranges.

24. The method of Claim 23 wherein the step of allocating remaining server bandwidth further comprises the clients receiving the bandwidth equally to the extent of their respective ranges.

25. The method of Claim 17 wherein the maximized value of the control variable can be determined by:

i) determining a maximimum and minimum flow rate for each client;

ii) determining a range between the maximimum and mininmum flow rates in order to find a flow rate range;

iii) determining available bandwidth by finding the difference between an aggregate flow capacity and a sum of the minimum flow rate;

iv) determining a flow variable by dividing the unused bandwidth by the flow rate range;

v) prescribing the control variable to be the minimum flow rate added to the flow rate range if the flow varible is less than one or prescribing the control variable to be the minimum flow rate added to the flow rate range corrected by the flow variable if the flow favorable is greater than one such that the control variable is easily calculated for each client.

26. The method of Claim 17 wherein at least one session is a session bundle and:

1) the minimum flow constraint is computed as the sum of the minimum flow rate constraints for all bundled sessions;

2) the maximum flow constraint is the least of 1) the sum of the maximum individual flow rate constraints of each session and 2) the flow capacity of the channel shared among the bundled sessions; and

3) the target flow rate is computed for the session is apportioned among the bundled constituent sessions.

27. The method of Claim 26 wherein the bundled session is an advertisement.

28. A system for allocating bandwidth between a server device and at least one client device, the system comprising:

a call acceptance module operative to receive an incoming request for service;

a flow regulator configured to deliver content at a modulated target flow rate, the content being delivered between the server device and a respective client device when a call is accepted by the call acceptance module; and

a flow optimizer configured to modulate the target flow rate of the flow regulator in order to optimize the aggregate flow of content.

29. The system of Claim 28 wherein the flow optimizer is configured to modulate the flow rate of the flow regulator in order to optimize charges for the content.

30. The system of Claim 29 wherein the flow regulator is configured to deliver the modulated flow rate of content in response to the control variable.

31. The system of Claim 28 wherein the flow optimizer is configured to determine a control variable which corresponds to an optimized flow rate.

32. The system of Claim 31 wherein the flow optimizer is configured to generate a cost function of the control variable that corresponds to a maximized value of the control variable.

33. The system of Claim 28 wherein the flow regulator is configured to deliver the modulated flow rate of content in response to the control variable.

34. The system of Claim 28 wherein the flow optimizer is configured to determine a maximized value of the control variable by:

i) determining a maximum and minimum flow rate for each client;

ii) determining a range between the maximum and minimum flow rates in order to find a flow rate range;

iii) determining unused bandwidth by finding the difference between an aggregate flow capacity and a sum of the minimum flow rate;

iv) determining a flow variable by dividing the unused bandwidth by the flow rate range;

v) prescribing the control variable to be the minimum flow rate added to the flow rate range if the flow variable is less than one or prescribing the control variable to be the minimum flow rate added to the flow rate range corrected by the flow variable if the flow favorable is greater than one such that the control variable is easily calculated for each client.

35. The system of Claim 33 wherein the call acceptance module is configured to accept a call based upon the value of the control variable.

36. A method of bandwidth allocation for delivery of stored digital content from at least one server device to at least one client device by way of a network, the method comprising the steps of:

a) prescribing a control variable which represents a target flow rate from the server to each client device based upon the amount of buffer of the client;

b) determining time-varying constraints on the flow rate of the content;

c) determining a cost function of the control variables for all clients in response to the size of the client's buffer; and

d) prescribing bandwidth to all clients based upon the value of the control variables that maximized the cost function.

37. A method for apportioning a given total flow rate (bandwidth) among a plurality of sessions for clients, the method comprising the steps of:

a) computing a sum of minimum flow rate constraints for each session;

b) computing a sum of flow rate ranges for all active clients;

c) computing a difference between the given total flow rate and a sum of the flow rate minima;

d) computing a factor as the ratio of the difference over the sum of the flow rate ranges;

e) if the factor exceeds 1, setting the flow rate to the maximum allowed client flow rate; and

f) if the factor is less than 1, computing the flow rate by multiplying the client range by the factor and then adding the result to the minimum allowed client flow rate.

38. The method of Claim 37 wherein the clients are distinguished by their cost of service and bandwidth is apportioned to clients iteratively, the amount apportioned to each client in a cost category is the amount remaining from prior allocations to clients in higher cost categories.

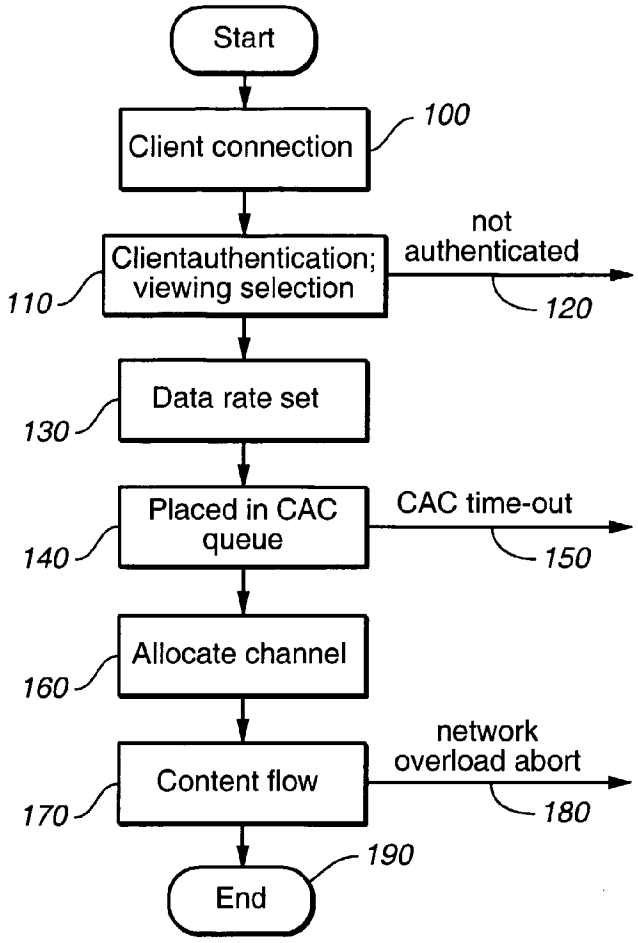
Start
Client connection
100
Clientauthentication; viewing selection
110
not authenticated
120
Data rate set
130
Placed in CAC queue
140
CAC time-out
150
Allocate channel
160
Content flow
170
network overload abort
180
End
190

FIG._1

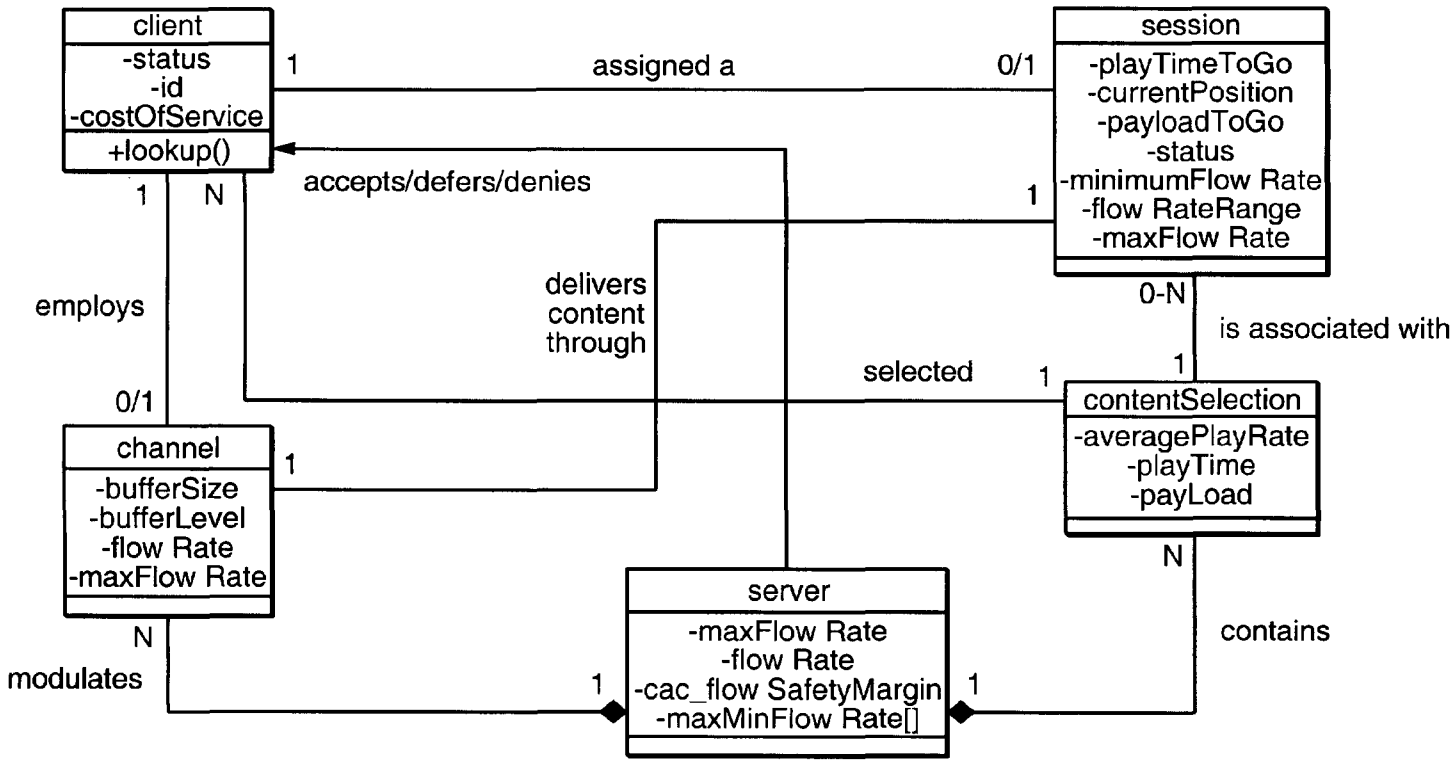
client
-status
-id
-costOfService
+lookup()
1
assigned a
0/1
session
-playTimeToGo
-currentPosition
-payloadToGo
-status
-minimumFlow Rate
-flow RateRange
-maxFlow Rate
1
N
accepts/defers/denies
1
employs
delivers
content
through
0-N
is associated with
selected
1
1
contentSelection
-averagePlayRate
-playTime
-payLoad
0/1
channel
-bufferSize
-bufferLevel
-flow Rate
-maxFlow Rate
1
N
server
-maxFlow Rate
-flow Rate
-cac_flow SafetyMargin
-maxMinFlow Rate[]
contains
modulates
1
1

FIG._2

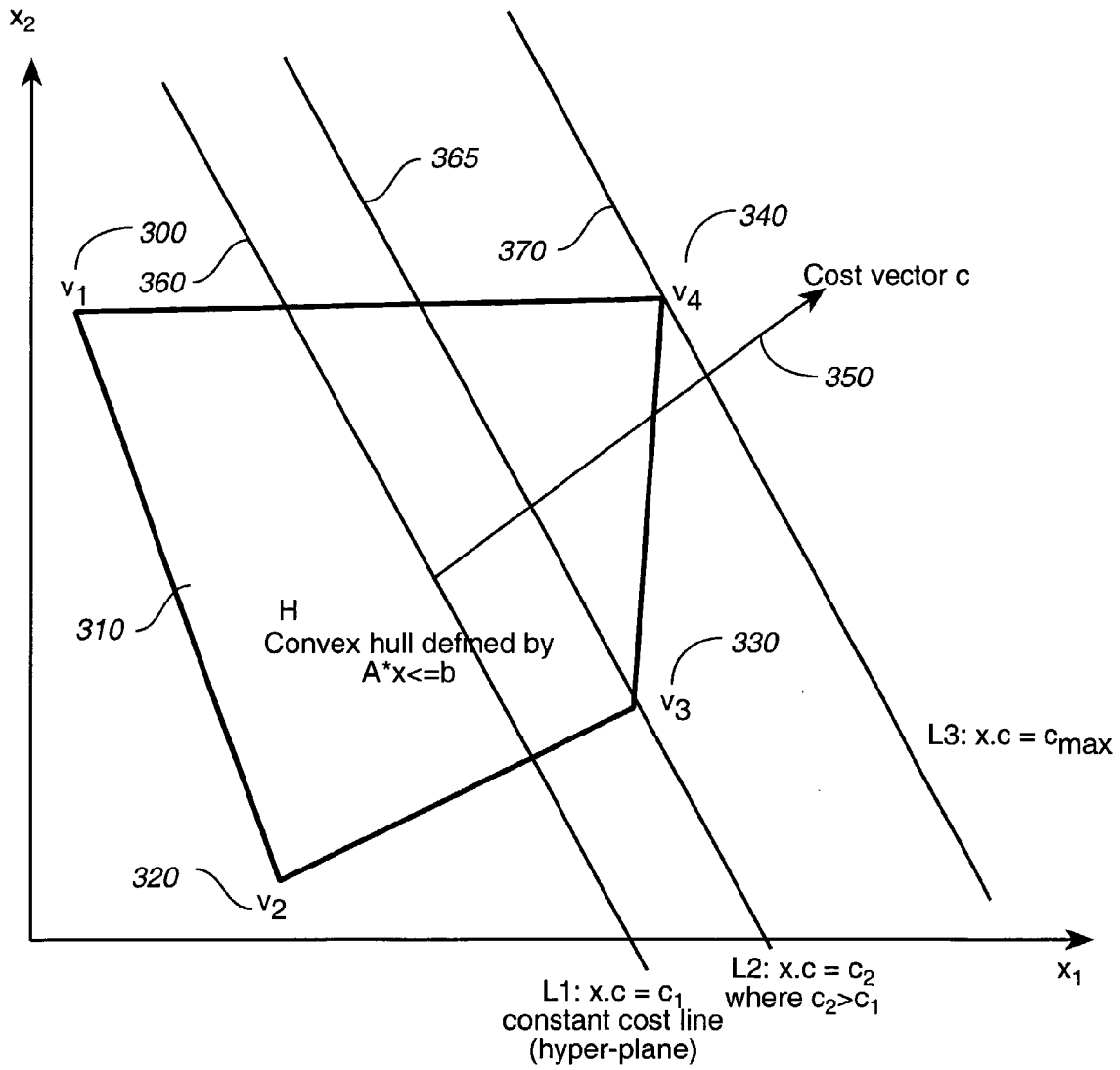
x2
365
300
370
340
v1
360
v4
Cost vector c
350
310
H
Convex hull defined by
A*x<=b
330
v3
L3: x.c = cmax
320
v2
x1
L1: x.c = c1
constant cost line
(hyper-plane)
L2: x.c = c2
where c2>c1

FIG._3

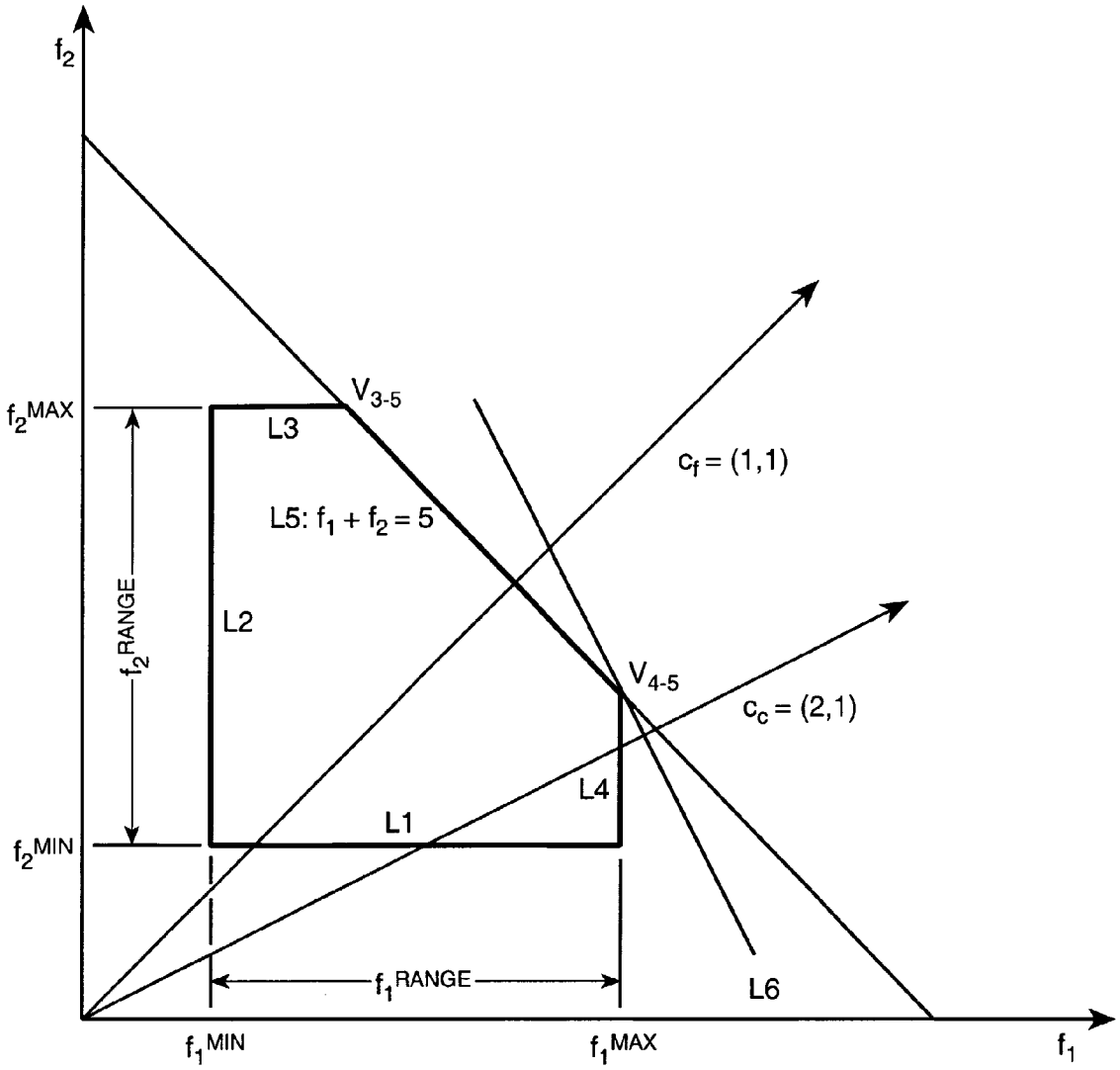
f2
f2MAX
f2MIN
f2RANGE
V3-5
L3
L5: f1 + f2 = 5
L2
V4-5
L4
L1
cf = (1,1)
cc = (2,1)
L6
f1RANGE
f1MIN
f1MAX
f1

FIG._4a

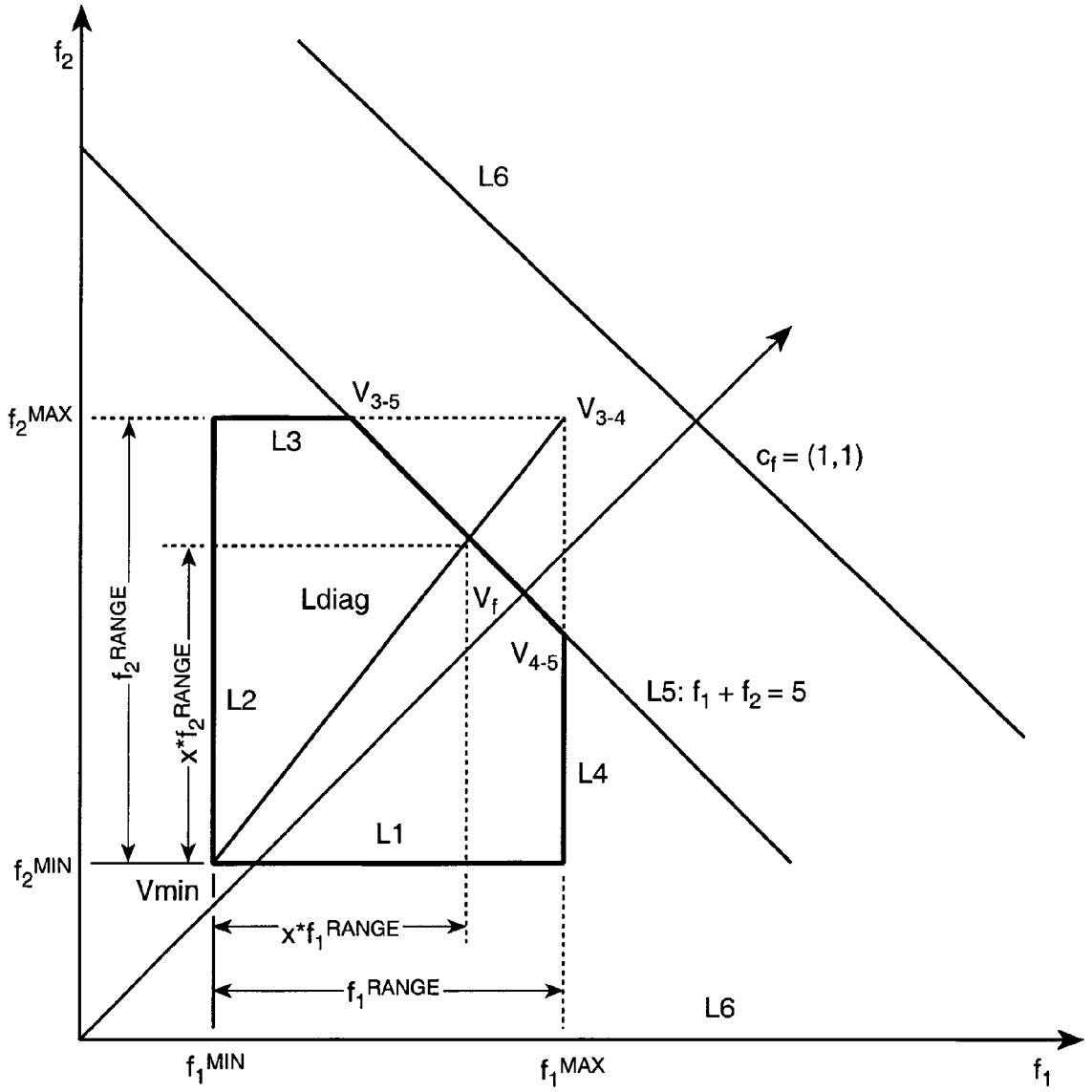
f2
L6
f2MAX
V3-5
V3-4
L3
cf = (1,1)
Ldiag
Vf
V4-5
f2RANGE
x*f2RANGE
L2
L5: f1 + f2 = 5
L4
L1
f2MIN
Vmin
x*f1RANGE
f1RANGE
L6
f1MIN
f1MAX
f1

FIG._4b

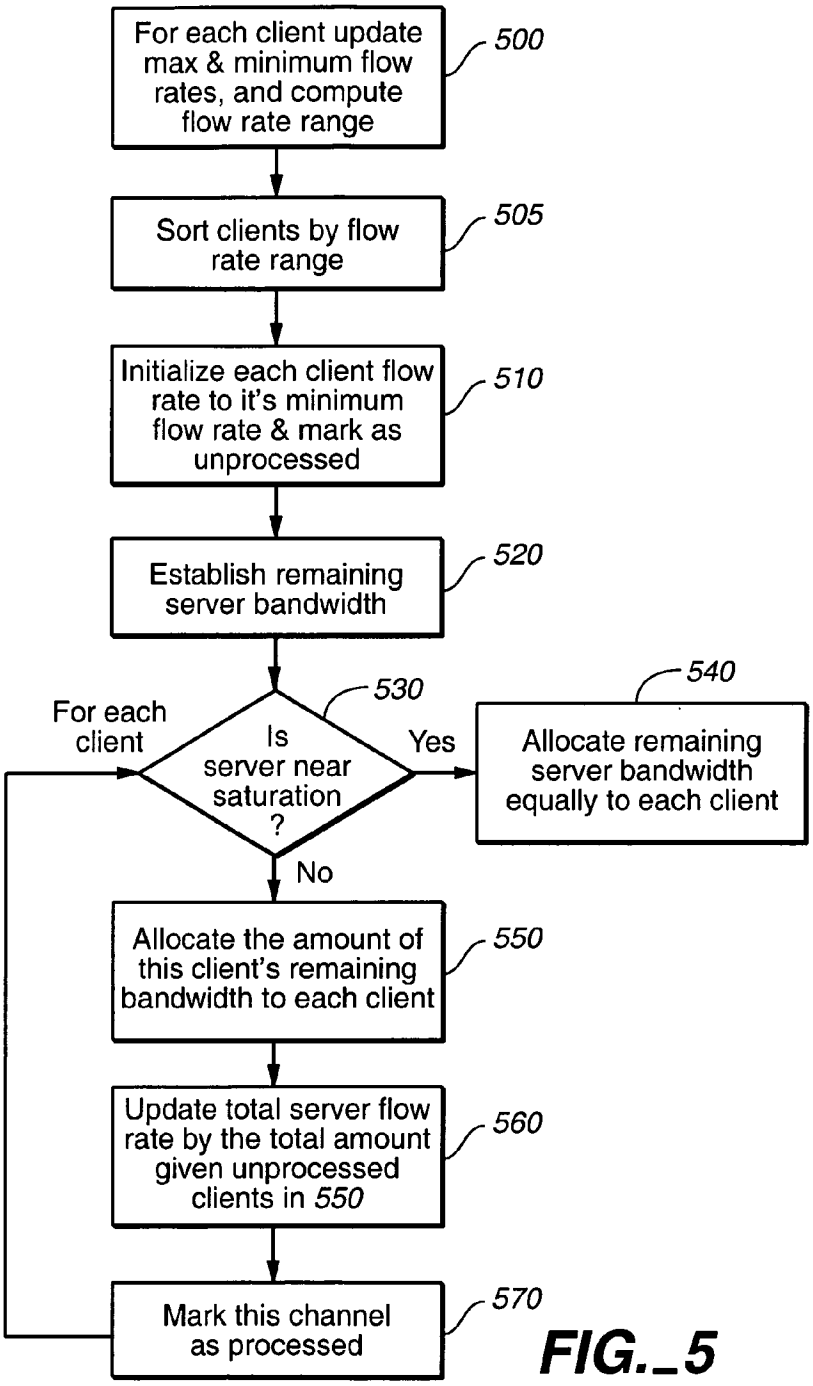
For each client update max & minimum flow rates, and compute flow rate range
500
Sort clients by flow rate range
505
Initialize each client flow rate to it's minimum flow rate & mark as unprocessed
510
Establish remaining server bandwidth
520
530
For each client
Is server near saturation ?
Yes
No
540
Allocate remaining server bandwidth equally to each client
Allocate the amount of this client's remaining bandwidth to each client
550
Update total server flow rate by the total amount given unprocessed clients in 550
560
Mark this channel as processed
570

FIG._5

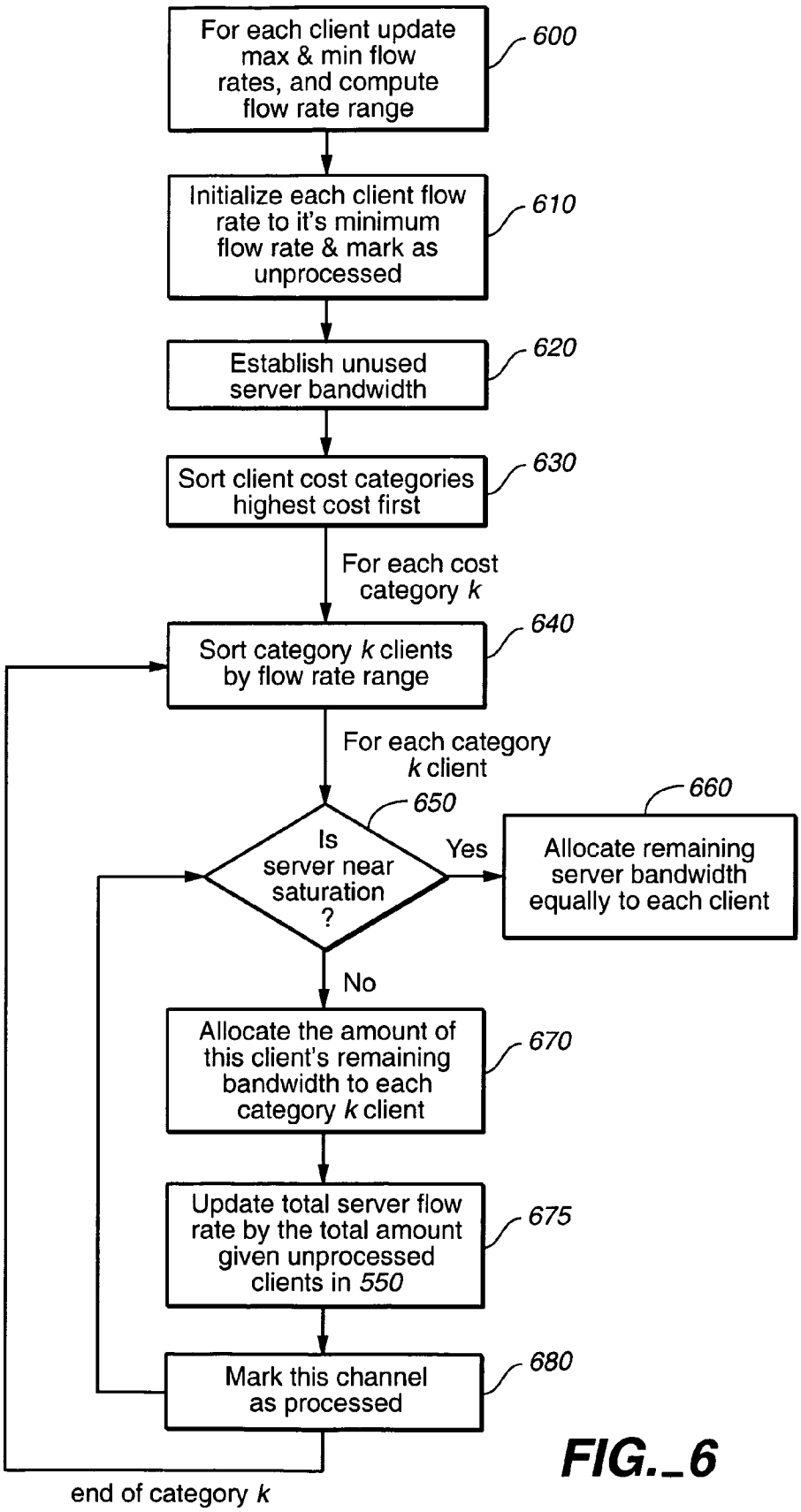
For each client update max & min flow rates, and compute flow rate range
600
Initialize each client flow rate to it's minimum flow rate & mark as unprocessed
610
Establish unused server bandwidth
620
Sort client cost categories highest cost first
630
For each cost category k
Sort category k clients by flow rate range
640
For each category k client
650
Is server near saturation ?
Yes
660
Allocate remaining server bandwidth equally to each client
No
Allocate the amount of this client's remaining bandwidth to each category k client
670
Update total server flow rate by the total amount given unprocessed clients in 550
675
Mark this channel as processed
680
end of category k

FIG._6

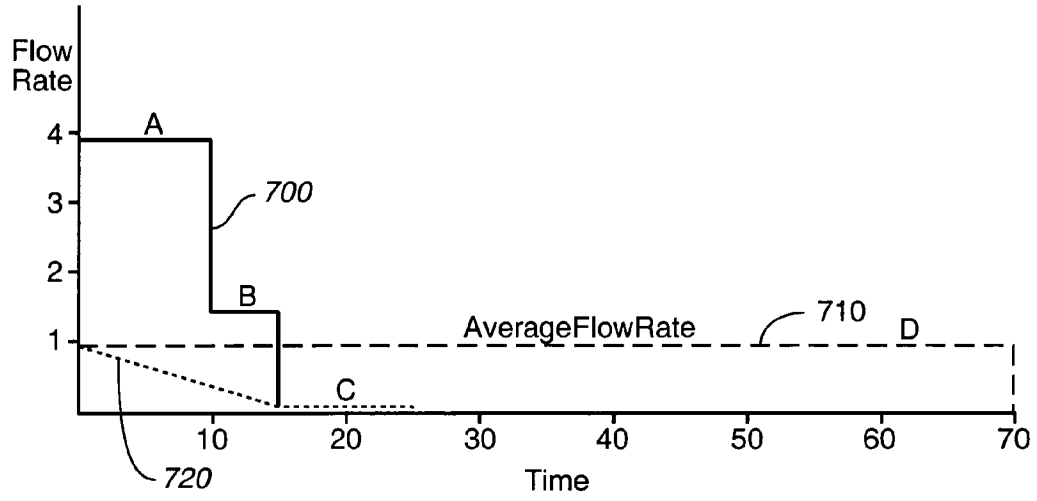
Flow Rate
4
3
2
1
A
B
C
D
700
710
720
AverageFlowRate
10
20
30
40
50
60
70
Time

FIG._7

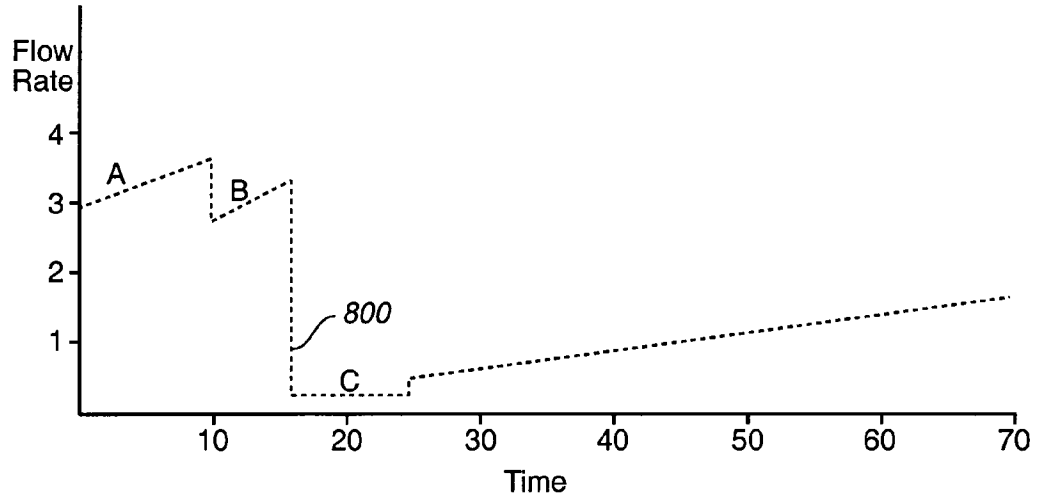
Flow Rate
4
3
2
1
A
B
C
800
10
20
30
40
50
60
70
Time

FIG._8

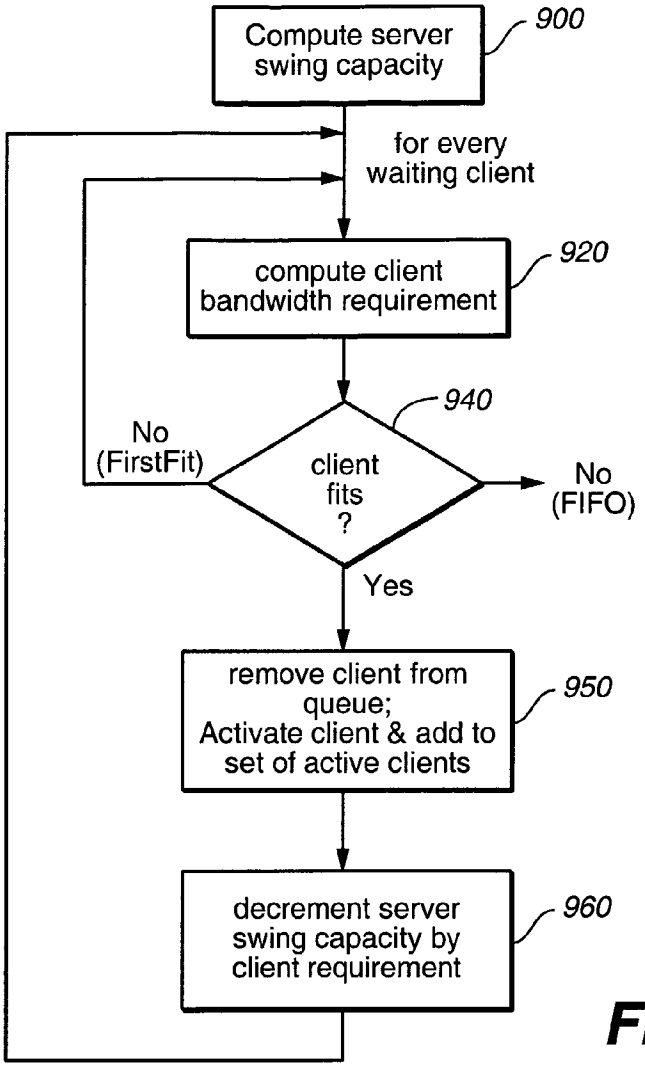
Compute server swing capacity
900
for every waiting client
compute client bandwidth requirement
920
940
No (FirstFit)
client fits ?
No (FIFO)
Yes
remove client from queue; Activate client & add to set of active clients
950
decrement server swing capacity by client requirement
960

FIG._9

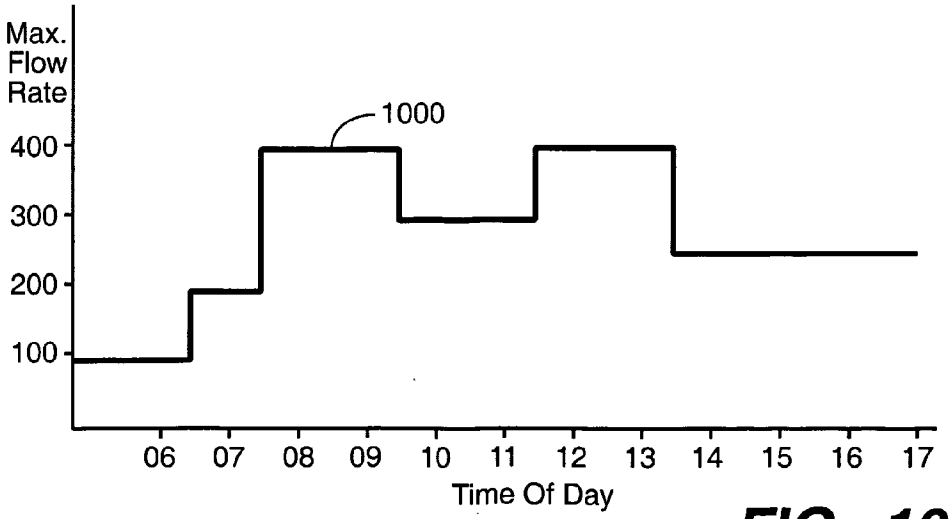
Max. Flow Rate
1000
400
300
200
100
06
07
08
09
10
11
12
13
14
15
16
17
Time Of Day

FIG._10

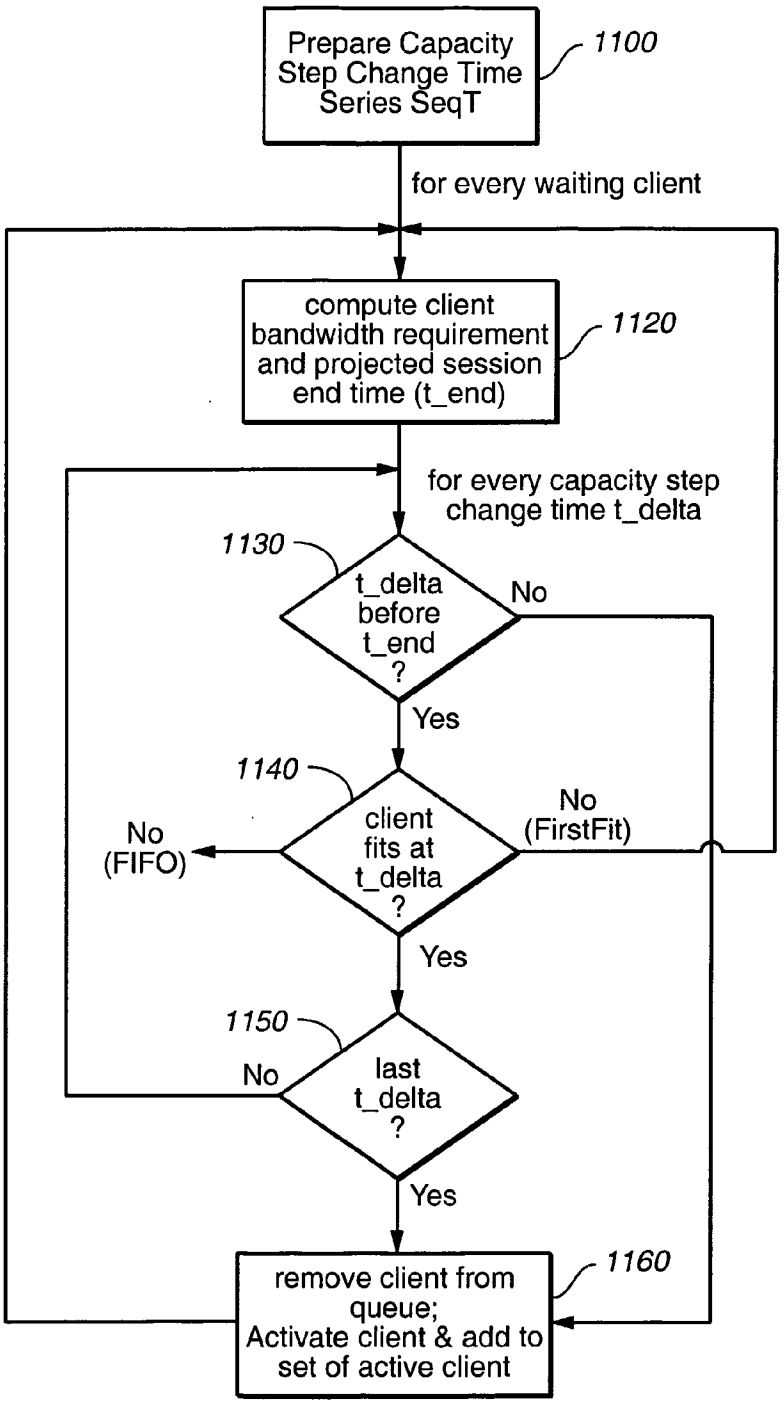
Prepare Capacity Step Change Time Series SeqT
1100
for every waiting client
compute client bandwidth requirement and projected session end time (t_end)
1120
for every capacity step change time t_delta
1130
t_delta before t_end ?
No
Yes
1140
client fits at t_delta ?
No (FIFO)
No (FirstFit)
Yes
1150
last t_delta ?
No
Yes
remove client from queue; Activate client & add to set of active client
1160

FIG._11

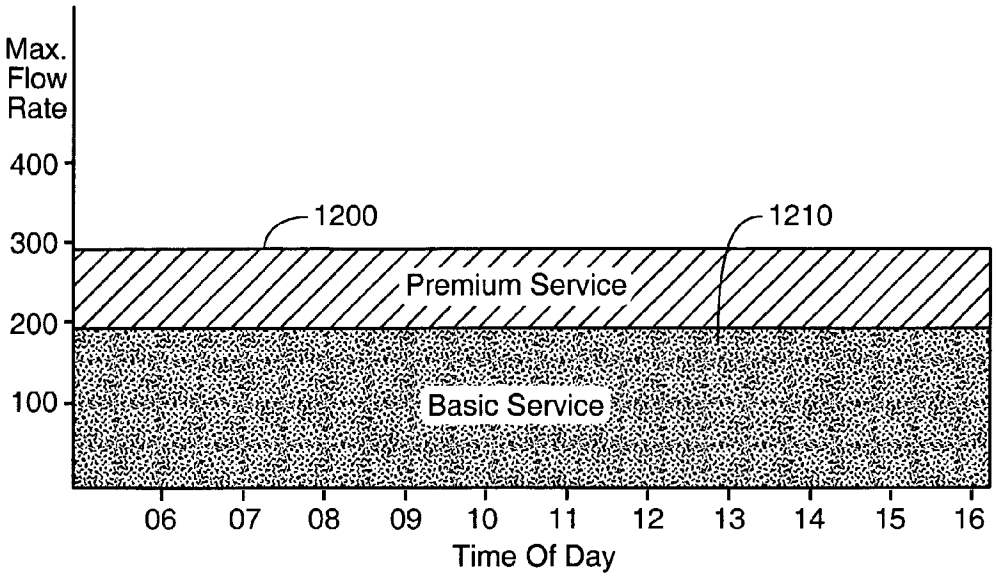
Max.
Flow
Rate
400
300
200
100
1200
1210
Premium Service
Basic Service
06
07
08
09
10
11
12
13
14
15
16
Time Of Day

FIG._12

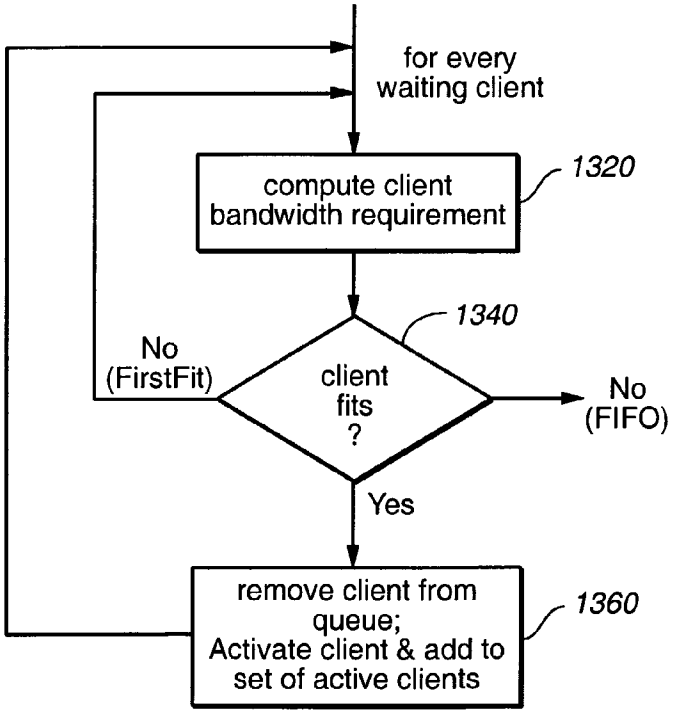
for every
waiting client
compute client
bandwidth requirement
1320
1340
No
(FirstFit)
client
fits
?
No
(FIFO)
Yes
remove client from
queue;
Activate client & add to
set of active clients
1360

FIG._13

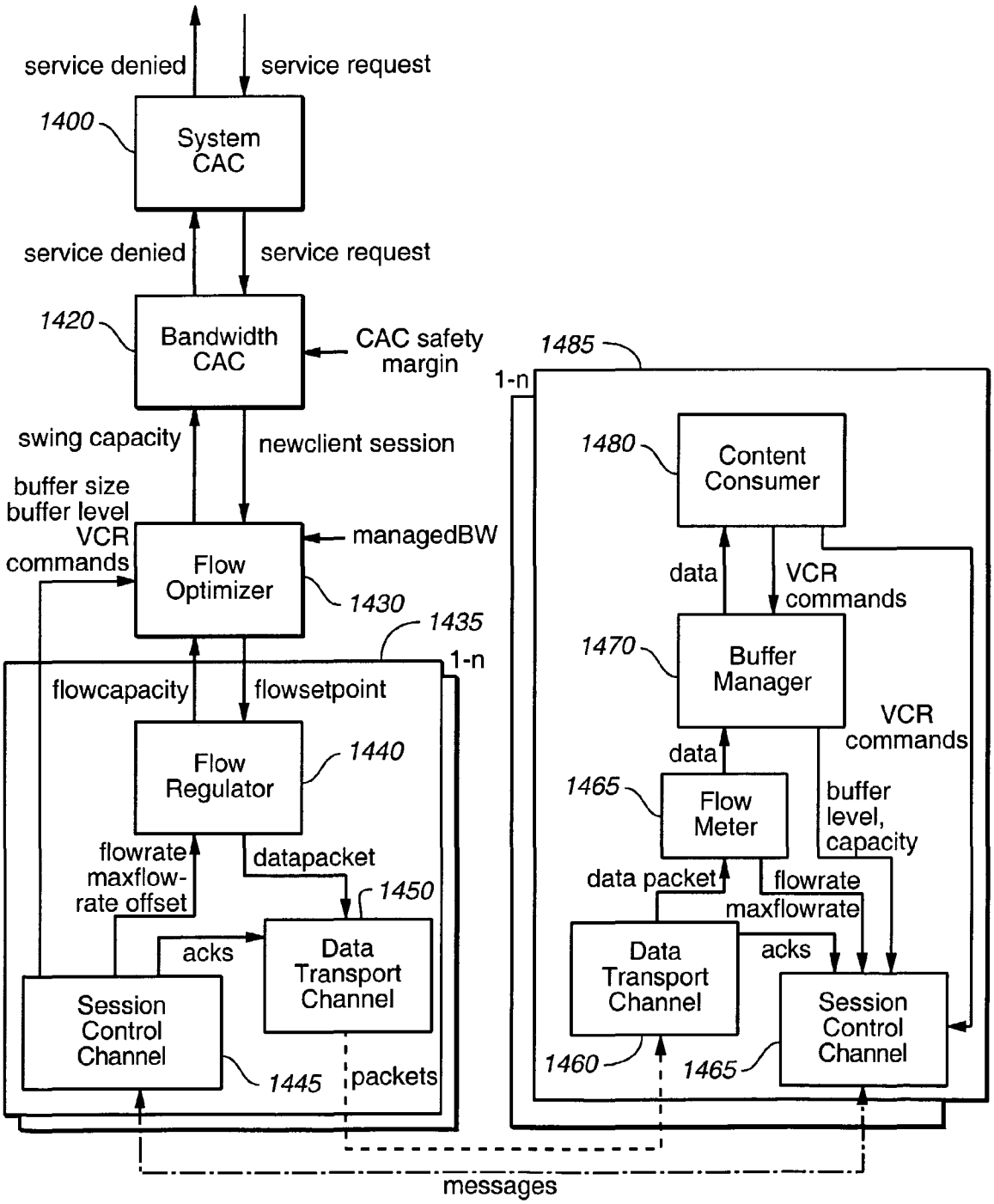
service denied
service request
1400
System CAC
service denied
service request
1420
Bandwidth CAC
CAC safety margin
swing capacity
newclient session
buffer size
buffer level
VCR commands
managedBW
Flow Optimizer
1430
1435
1-n
flowcapacity
flowsetpoint
Flow Regulator
1440
flowrate
maxflow-rate offset
datapacket
1450
acks
Data Transport Channel
Session Control Channel
1445
packets
1485
1-n
1480
Content Consumer
data
VCR commands
1470
Buffer Manager
VCR commands
data
1465
Flow Meter
buffer level, capacity
data packet
flowrate
maxflowrate
Data Transport Channel
acks
Session Control Channel
1460
1465
messages

FIG._14

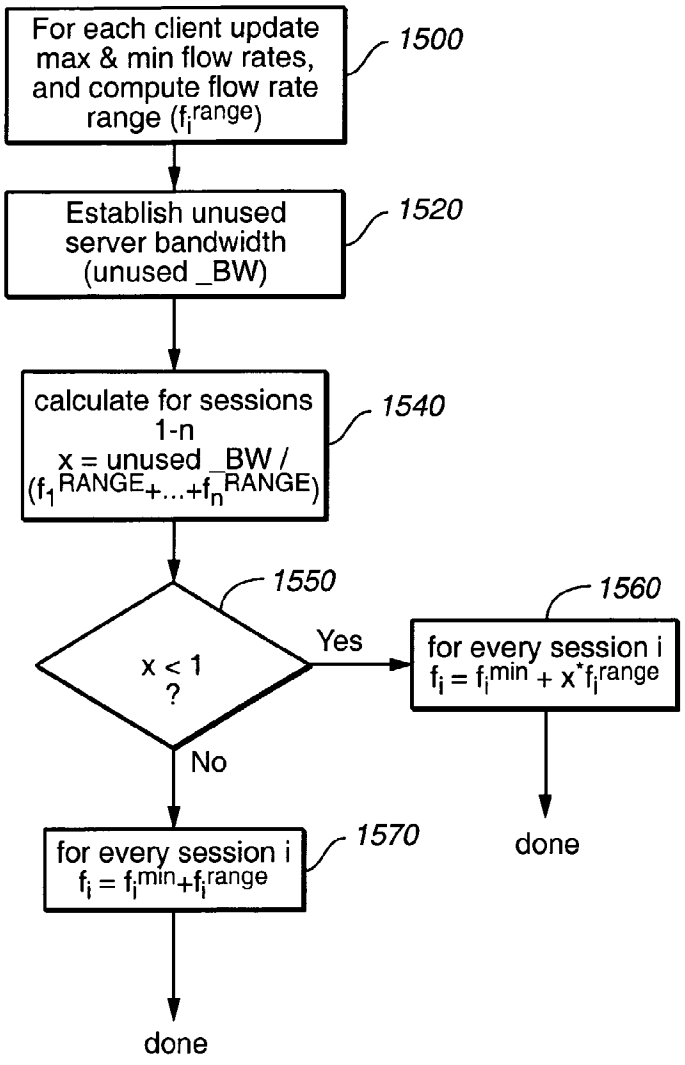
For each client update max & min flow rates, and compute flow rate range (f_i^{range})
1500
Establish unused server bandwidth (unused _BW)
1520
calculate for sessions 1-n x = unused _BW / (f_1^{RANGE}+...+f_n^{RANGE})
1540
1550
x < 1 ?
Yes
No
1560
for every session i $f_i = f_i^{min} + x^* f_i^{range}$
done
for every session i $f_i = f_i^{min} + f_i^{range}$
1570
done

FIG._15

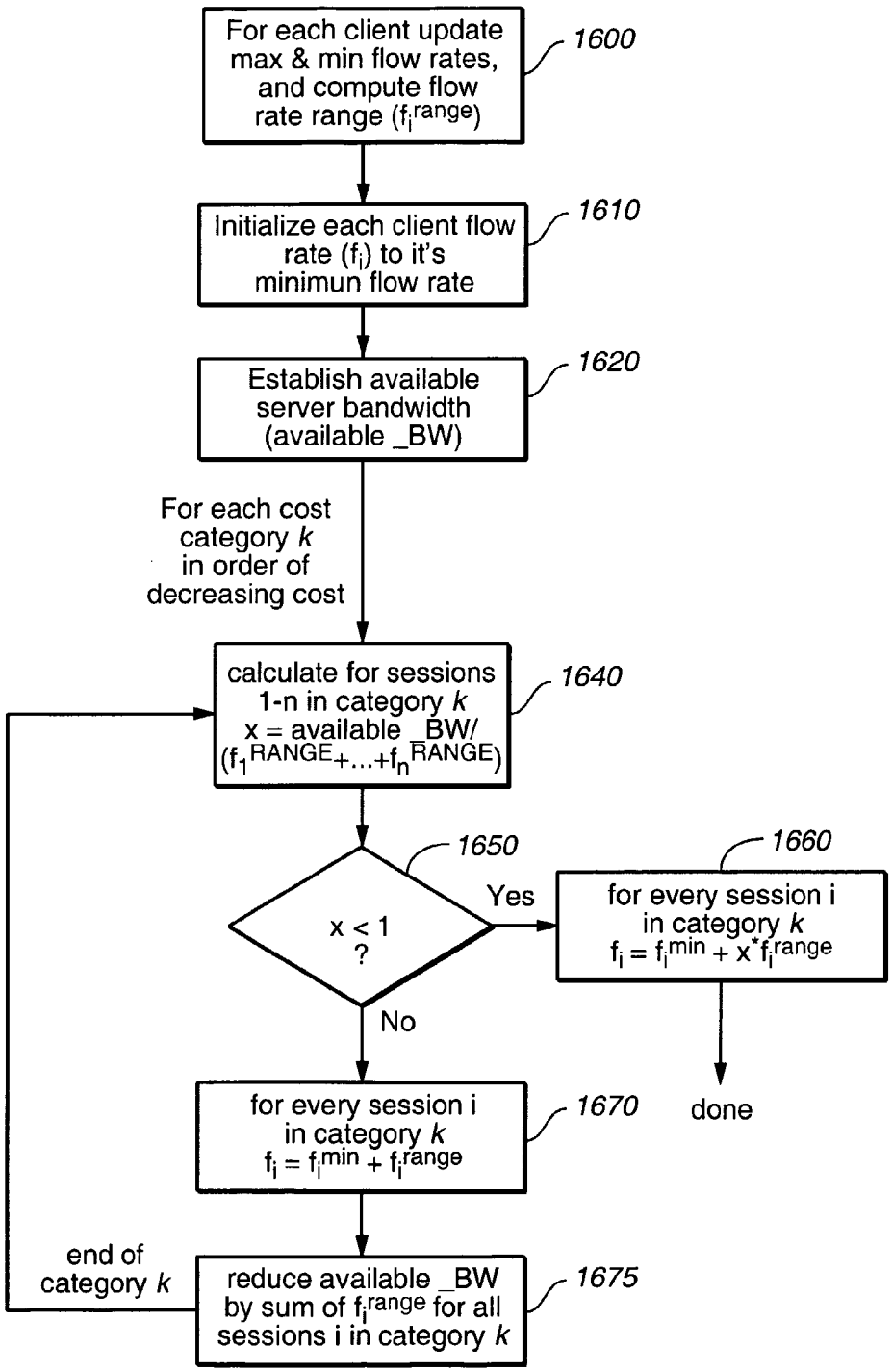
For each client update max & min flow rates, and compute flow rate range (f_i^{range})
1600
Initialize each client flow rate (f_i) to it's minimun flow rate
1610
Establish available server bandwidth (available _BW)
1620
For each cost category k in order of decreasing cost
calculate for sessions 1-n in category k x = available _BW/ (f_1^{RANGE}+...+f_n^{RANGE})
1640
1650
x < 1 ?
Yes
No
1660
for every session i in category k $f_i = f_i^{min} + x^* f_i^{range}$
done
for every session i in category k $f_i = f_i^{min} + f_i^{range}$
1670
end of category k
reduce available _BW by sum of f_i^{range} for all sessions i in category k
1675

FIG._16

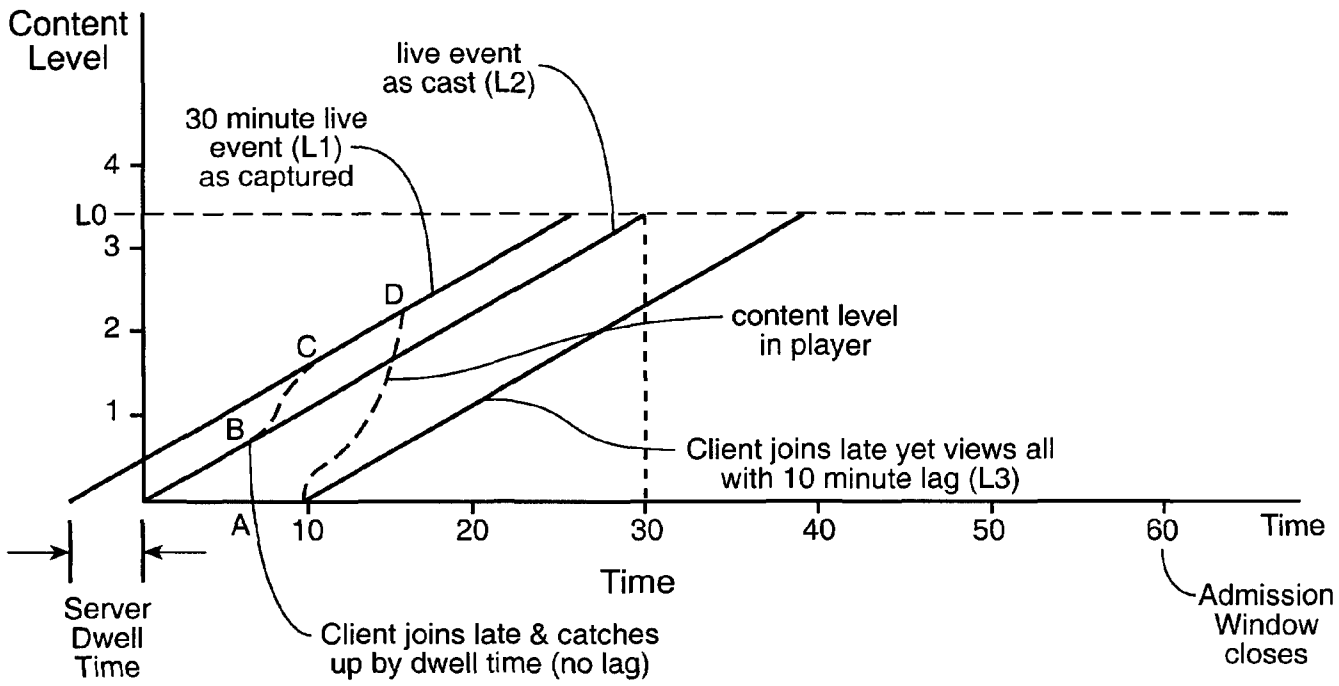
Content Level
live event as cast (L2)
30 minute live event (L1) as captured
4
L0
3
2
1
D
C
B
A
content level in player
Client joins late yet views all with 10 minute lag (L3)
10
20
30
40
50
60
Time
Time
Server Dwell Time
Client joins late & catches up by dwell time (no lag)
Admission Window closes

FIG._17

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), by mail or fax, or via the USPTO patent electronic filing system.

By mail, send to: Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

By fax, send to: (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications. **Because electronic patent issuance may occur shortly after issue fee payment, any desired continuing application should preferably be filed prior to payment of this issue fee in order not to jeopardize copendency.**

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

70560 7590 03/25/2024
KW LAW LLP (Dish Technologies L.L.C.)
6122 N 7th St Suite D
Phoenix, AZ 85014

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being transmitted to the USPTO via the USPTO patent electronic filing system or by facsimile to (571) 273-2885, on the date below.

(Typed or printed name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
18/069,450	12/21/2022	DAVID F. BRUECK	9401-00279	8508

TITLE OF INVENTION: APPARATUS, SYSTEM, AND METHOD FOR MULTI-BITRATE CONTENT STREAMING

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$1200	$0.00	$1200.00	$0	06/25/2024

EXAMINER	ART UNIT	CLASS-SUBCLASS
PATEL, CHIRAG R	2454	709-219000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

❑ Change of correspondence address (or Change of Correspondence Address form PTO/AIA/122 or PTO/SB/122) attached.

❑ "Fee Address" indication (or "Fee Address" Indication form PTO/AIA/47 or PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 KW Law, LLP
2
3

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document must have been previously recorded, or filed for recordation, as set forth in 37 CFR 3.11 and 37 CFR 3.81(a). Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE: DISH Technologies L.L.C.
(B) RESIDENCE: (CITY and STATE OR COUNTRY): Englewood, CO

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ❑ Corporation or other private group entity ❑ Government

4a. Fees submitted: ☒ Issue Fee ❑ Publication Fee (if required)

4b. Method of Payment: *(Please first reapply any previously paid fee shown above)*

☒ Electronic Payment via the USPTO patent electronic filing system ❑ Enclosed check ❑ Non-electronic payment by credit card (Attach form PTO-2038)

☒ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment to Deposit Account No. 602406

5. **Change in Entity Status** (from status indicated above)

❑ Applicant certifying micro entity status. See 37 CFR 1.29

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.

❑ Applicant asserting small entity status. See 37 CFR 1.27

NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.

❑ Applicant changing to regular undiscounted fee status.

NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature /Brett Carlson/ Date April 12, 2024

Typed or printed name Brett Carlson Registration No. 39928

UNITED STATES
PATENT AND TRADEMARK OFFICE

P.O. Box 1450
Alexandria, VA 22313 - 1450
www.uspto.gov

ELECTRONIC ACKNOWLEDGEMENT RECEIPT

APPLICATION #	RECEIPT DATE / TIME	ATTORNEY DOCKET #
18/069,450	**04/12/2024 07:13:52 PM Z ET**	**9401-00279**

Title of Invention

APPARATUS, SYSTEM, AND METHOD FOR MULTI-BITRATE CONTENT STREAMING

Application Information

APPLICATION TYPE	Utility - Nonprovisional Application under 35 USC 111(a)	PATENT #	-
CONFIRMATION #	8508	FILED BY	BLAKE SCHEFFEY
PATENT CENTER #	65080253	FILING DATE	12/21/2022
CUSTOMER #	70560	FIRST NAMED INVENTOR	DAVID F. BRUECK
CORRESPONDENCE ADDRESS	-	AUTHORIZED BY	Brett Carlson

Documents

TOTAL DOCUMENTS: 2

DOCUMENT	PAGES	DESCRIPTION	SIZE (KB)
9401-00279_IFT_041224.pdf	1	Issue Fee Payment (PTO-85B)	143 KB
9401-00279_MFA_041224.pdf	2	Maintenance Fee Address Change	236 KB

Digest

DOCUMENT	MESSAGE DIGEST(SHA-512)
9401-00279_IFT_041224.pdf	65646EC26EB06581B8AA23F1E08DA036F74FFD47162D24009E E6BDD0C0259AD26BF7B93F050813D2288D91D3290E121458F C688C120E2713BCEC40169DDE8329

9401-00279_MFA_041224.pdf D90B66F92EB303389C89859EB5CBBCFEC6264E72BB5504C2E17B0B5E4DD8A1843120914B4E4C87526576B0B18AC117C60AAFC0C2B2C603E9605227A11EFB3E22

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Doc Code: MFEE.C.AD
Document Description: Maintenance Fee Address Change

PTO/SB/47 (11-21)
Approved for use through 11/30/2024. OMB 0651-0016
U.S. Patent and Trademark Office; U.S. Department of Commerce
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

"FEE ADDRESS" INDICATION FORM

Address to:
Mail Stop Maintenance Fee
Director of the United States
Patent and Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450

-OR-

Fax to: 571-273-6500

INSTRUCTIONS: The issue fee must have been paid for application(s) listed on this form. In addition, only an address represented by a Customer Number can be established as the fee address for maintenance fee purposes (hereafter, fee address). A fee address should be established when correspondence related to maintenance fees should be mailed to a different address than the correspondence address for the application.
When to check the first box below: If you have a Customer Number to represent the fee address.
When to check the second box below: If you have no Customer Number representing the desired fee address, in which case a completed Request for Customer Number (PTO/SB/125) must be attached to this form. For more information on Customer Numbers, see section 403 of the Manual of Patent Examining Procedure (MPEP).

For the following listed application(s), please recognize as the "Fee Address" under the provisions of 37 CFR 1.363 the address associated with:

☑ Customer Number 000197

OR

☐ The attached Request for Customer Number (PTO/SB/125) form.

PATENT NUMBER (if known)	APPLICATION NUMBER
	18/069,450

Completed by (check one):

☐ Applicant/Inventor

/Brett A. Carlson/
Signature

☑ Attorney or agent of record 39,928 (Reg. No.)

Brett A. Carlson
Typed or printed name

☐ Assignee of record of the entire interest. See 37 CFR 3.71. Statement under 37 CFR 3.73(b) (Form PTO/SB/96) is enclosed or was filed on _____ (Date)

480-241-8219
Requester's telephone number

April 12, 2024
Date

NOTE: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required. If the assignee is a juristic entity, this form must be signed by a patent practitioner (attorney or agent) of record. Submit multiple forms if more than one signature is required (see below*).

☐ *Total of _____ PTO/SB/47 forms are submitted

A Federal agency may not conduct or sponsor, and a person is not required to respond to, nor shall a person be subject to a penalty for failure to comply with an information collection subject to the requirements of the Paperwork Reduction Act of 1995, unless the information collection has a currently valid OMB Control Number. The OMB Control Number for this information collection is 0651-0016. Public burden for this form is estimated to average 5 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the information collection. Send comments regarding this burden estimate or any other aspect of this information collection, including suggestions for reducing this burden to the Chief Administrative Officer, United States Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450 or email InformationCollection@uspto.gov. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing this form, please call 1-800-PTO-9199 and then select option 2.

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The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. The United States Patent and Trademark Office (USPTO) collects this information under authority of 5 CFR 1.290. The information in this system of records is used to manage all records of applicant including name, citizenship, residence, post office address and other information with respect to inventors and their legal representatives pertaining to the applicant's activities in connection with the invention for which a patent is sought. This information is protected from disclosure to third parties in accordance with the Privacy Act.

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United States Patent and Trademark Office

Office of the Chief Financial Officer

Document Code:WFEE

User :Sengpheth Sandara

Refund Accounting Date:04/15/2024

Effective Date	Sale Item Reference Number	Refund Total
04/15/2024	18069450	$1,200.00

Document Number	Fee Code	Fee Code Description	Amount Paid	Payment Method	Account Number
I20244ED31577413	1501	UTILITY APPL ISSUE FEE	$1,200.00	Visa	**********6960

United States Patent and Trademark Office

Office of the Chief Financial Officer

Document Code:WFEE

User :Sengpheth Sandara

Sale Adjustment Accounting Date:04/15/2024

Effective Date	Sale Accounting Date	Sale Item Reference Number
04/15/2024	04/15/2024	18069450

Document Number	Fee Code	Fee Code Description	Amount Paid	Payment Method
I20244ED31577413	1501	UTILITY APPL ISSUE FEE	$1,200.00	Visa

United States Patent and Trademark Office

Office of the Chief Financial Officer

Document Code:WFEE

User :Brian Curran

Sale Accounting Date:04/15/2024

Sale Item Reference Number	Effective Date
18069450	04/12/2024

Document Number	Fee Code	Fee Code Description	Amount Paid	Payment Method
I20244EE13295303	1501	UTILITY APPL ISSUE FEE	$1,200.00	Credit Card

UNITED STATES PATENT AND TRADEMARK OFFICE

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
18/069,450	12/21/2022	DAVID F. BRUECK	9401-00279	8508

70560 7590 04/24/2024
KW LAW LLP (Dish Technologies L.L.C.)
6122 N 7th St Suite D
Phoenix, AZ 85014

EXAMINER
PATEL, CHIRAG R

ART UNIT	PAPER NUMBER
2454	

NOTIFICATION DATE	DELIVERY MODE
04/24/2024	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

dish@kwlaw.co
ipdept@dish.com
uspto@dockettrak.com

Corrected ***Notice of Allowability***	**Application No.** 18/069,450	**Applicant(s)** BRUECK et al.	
	Examiner CHIRAG R PATEL	**Art Unit** 2454	**AIA (FITF) Status** No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☑ This communication is responsive to the printer rush on April 12, 2024.
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

3. ☑ The allowed claim(s) is/are 11-30 . As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see **http://www.uspto.gov/patents/init_events/pph/index.jsp** or send an inquiry to **PPHfeedback@uspto.gov.**

4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

   Certified copies:

   a) ☐ All b) ☐ Some* c) ☐ None of the:

   1. ☐ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____ .

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____ .

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☑ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date 12/21/22.
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material _____.
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date. _____.
5. ☐ Examiner's Amendment/Comment
6. ☐ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____.

/CHIRAG R PATEL/
Primary Examiner, Art Unit 2454

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	18/069,450	BRUECK et al.
	Examiner	**Art Unit**
	CHIRAG R PATEL	2454

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

CLAIMS

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☑ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	03/09/2023	06/29/2023	11/17/2023	01/22/2024	03/13/2024	04/04/2024	04/18/2024		
	1	✓	-	-	-	-	-	-		
	2	✓	-	-	-	-	-	-		
	3	✓	-	-	-	-	-	-		
	4	✓	-	-	-	-	-	-		
	5	✓	-	-	-	-	-	-		
	6	✓	-	-	-	-	-	-		
	7	✓	-	-	-	-	-	-		
	8	✓	-	-	-	-	-	-		
	9	✓	-	-	-	-	-	-		
	10	✓	-	-	-	-	-	-		
1	11	✓	=	=	=	=	=	=		
2	12	O	=	=	=	=	=	=		
3	13	O	=	=	=	=	=	=		
4	14	O	=	=	=	=	=	=		
5	15	O	=	=	=	=	=	=		
6	16	O	=	=	=	=	=	=		
7	17	O	=	=	=	=	=	=		
8	18	O	=	=	=	=	=	=		
9	19	O	=	=	=	=	=	=		
10	20	O	=	=	=	=	=	=		
11	21	O	=	=	=	=	=	=		
12	22	✓	=	=	=	=	=	=		
13	23	O	=	=	=	=	=	=		
14	24	O	=	=	=	=	=	=		
15	25	O	=	=	=	=	=	=		
16	26	O	=	=	=	=	=	=		
17	27	O	=	=	=	=	=	=		
18	28	O	=	=	=	=	=	=		
19	29	O	=	=	=	=	=	=		
20	30	O	=	=	=	=	=	=		

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	18/069,450	BRUECK et al.
	Examiner	**Art Unit**
	CHIRAG R PATEL	2454

CPC - Searched*		
Symbol	**Date**	**Examiner**
H04L47/30, H04L65/80, H04L47/263, H04L47/10	03/09/2023	C.P.

CPC Combination Sets - Searched*		
Symbol	**Date**	**Examiner**

US Classification - Searched*			
Class	**Subclass**	**Date**	**Examiner**

* See search history printout included with this form or the SEARCH NOTES box below to determine the scope of the search.

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	18/069,450	BRUECK et al.
	Examiner	**Art Unit**
	CHIRAG R PATEL	2454

Search Notes		
Search Notes	**Date**	**Examiner**
PE2E Search	03/08/2023	C.P.
Google Patents - Scholar	03/08/2023	C.P.
IP.COM	03/08/2023	C.P.
Inventor - Double Patent Search	03/08/2023	C.P.
Reviewed references cited in IPR and IDS	11/17/2023	C.P.
IPR2024-00043 Reviewed Petition for Inter Partes Review of U.S. Patent No. 11,470,138 on March 11, 2024	03/11/2024	C.P.
IPR2024-00043 Reviewed Petition for Inter Partes Review of U.S. Patent No. 11,677,798 on March 11, 2024	03/11/2024	C.P.
PR2024-00044 Reviewed Petition for Inter Partes Review of U.S. Patent No. 11,470,138 on March 11, 2024	03/11/2024	C.P.
IPR2024-00043, -00044, -00045, -00046, -00047, -00048, Reviewed Patent Owner's Preliminary Responses under 35 U.S.C. § 313 AND 37 C.F.R. § 42.107 on March 12, 2024	03/11/2024	C.P.
IPR2024-00048 Reviewed Petition for Inter Partes Review of U.S. Patent No. 8,868,772 on March 12, 2024	03/12/2024	C.P.
IPR 2024-00512 Reviewed Petition for Inter Partes Review of U.S. Patent No. 11,470,138 on March 12, 2024	03/12/2024	C.P.
PR2024-00517 Reviewed Petition for Inter Partes Review of U.S. Patent No. 11,470,138 on March 12, 2024	03/12/2024	C.P.
PR2024-00517 Reviewed Petition for Inter Partes Review of U.S. Patent No. 11,677,798 on March 12, 2024	03/12/2024	C.P.
IPR2024-00519 Reviewed Petition for Inter Partes Review of U.S. Patent No. 8,868,772 on March 12, 2024	03/12/2024	C.P.
Reviewed all references and IPR listed on IDS filed on February 1, 2024	03/13/2024	C.P.

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	18/069,450	BRUECK et al.
	Examiner	**Art Unit**
	CHIRAG R PATEL	2454

Interference Search			
US Class/CPC Symbol	**US Subclass/CPC Group**	**Date**	**Examiner**
H04L	H04L47/30, H04L65/80, H04L47/263, H04L47/10	06/29/2023	C.P.

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	18/069,450	BRUECK et al.
	Examiner	**Art Unit**
	CHIRAG R PATEL	2454

CPC						
Symbol					**Type**	**Version**
H04L	/	65	/	70	F	2022-05-01
H04L	/	47	/	801	I	2013-01-01
H04L	/	47	/	12	I	2013-01-01
G06F	/	16	/	71	I	2019-01-01
G06F	/	16	/	183	I	2019-01-01
H04N	/	7	/	24	I	2013-01-01
H04N	/	21	/	23439	I	2013-01-01
H04N	/	21	/	4331	I	2013-01-01
H04N	/	21	/	84	I	2013-01-01
H04N	/	21	/	8456	I	2013-01-01
H04L	/	65	/	80	I	2013-01-01
H04L	/	65	/	61	I	2022-05-01
H04L	/	65	/	65	I	2022-05-01
H04L	/	65	/	1101	I	2022-05-01
H04L	/	67	/	60	I	2022-05-01
H04L	/	67	/	568	I	2022-05-01
H04L	/	67	/	02	I	2013-01-01
H04L	/	65	/	1069	I	2013-01-01
H04N	/	21	/	2662	I	2013-01-01

CPC Combination Sets								
Symbol					**Type**	**Set**	**Ranking**	**Version**
	/		/					

NONE (Assistant Examiner)	(Date)	**Total Claims Allowed:** 20	
/CHIRAG R PATEL/ Primary Examiner, Art Unit 2454 (Primary Examiner)	18 April 2024 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 1

U.S. Patent and Trademark Office

Part of Paper No.: 20240418

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	18/069,450	BRUECK et al.
	Examiner	**Art Unit**
	CHIRAG R PATEL	2454

INTERNATIONAL CLASSIFICATION				
CLAIMED				
H04L	/	65	/	70

NON-CLAIMED				
	/		/	

US ORIGINAL CLASSIFICATION	
CLASS	**SUBCLASS**

CROSS REFERENCES(S)						
CLASS	**SUBCLASS (ONE SUBCLASS PER BLOCK)**					

NONE (Assistant Examiner) (Date)		**Total Claims Allowed:** 20	
/CHIRAG R PATEL/ Primary Examiner, Art Unit 2454 (Primary Examiner) (Date)	18 April 2024	O.G. Print Claim(s) 1	O.G. Print Figure 1

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	18/069,450	BRUECK et al.
	Examiner	**Art Unit**
	CHIRAG R PATEL	2454

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☑ T.D. ☐ R.1.47

CLAIMS

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
	1		10	9	19	18	28								
	2	1	11	10	20	19	29								
	3	2	12	11	21	20	30								
	4	3	13	12	22										
	5	4	14	13	23										
	6	5	15	14	24										
	7	6	16	15	25										
	8	7	17	16	26										
	9	8	18	17	27										

NONE (Assistant Examiner)	(Date)	**Total Claims Allowed:** 20	
/CHIRAG R PATEL/ Primary Examiner, Art Unit 2454 (Primary Examiner)	18 April 2024 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 1

U.S. Patent and Trademark Office Part of Paper No.: 20240418

PTO/SB/08a (01-10)
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	18/069450
Filing Date	
First Named Inventor	David F. Brueck
Art Unit	
Examiner Name	
Attorney Docket Number	9401-00279

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That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

☒ See attached certification statement.

The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/BRETT A. CARLSON/	Date (YYYY-MM-DD)	2022-12-21
Name/Print	Brett A. Carlson	Registration Number	39928

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Bibliographic Data

Application No: 18/069,450

Foreign Priority claimed: ○ Yes ◉ No

35 USC 119 (a-d) conditions met: ☐ Yes ☑ No ☐ Met After Allowance

Verified and Acknowledged: /CHIRAG R PATEL/ [ ]

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Title: APPARATUS, SYSTEM, AND METHOD FOR MULTI-BITRATE CONTENT STREAMING

FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
12/21/2022	709	2454	9401-00279
RULE			

APPLICANTS

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R. DREW MAJOR, OREM, UT, UNITED STATES

CONTINUING DATA

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11673483 is a CIP of 11116783 04/28/2005 PAT 8868772

11116783 has PRO of 60566831 04/30/2004

FOREIGN APPLICATIONS

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	18069450
Filing Date	2022-12-21
First Named Inventor	David F. Brueck
Art Unit	2454
Examiner Name	Chirag R. Patel
Attorney Docket Number	9401-00279

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	18069450
Filing Date	2022-12-21
First Named Inventor	David F. Brueck
Art Unit	2454
Examiner Name	Chirag R. Patel
Attorney Docket Number	9401-00279

U.S.PATENTS Remove

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	18/069450
	Filing Date	
	First Named Inventor	David F. Brueck
	Art Unit	
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	Application Number	18/069450
	Filing Date	
	First Named Inventor	David F. Brueck
	Art Unit	
	Examiner Name	
	Attorney Docket Number	9401-00279

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APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
18/069,450	05/21/2024	11991234	9401-00279	8508

70560 7590 05/01/2024
KW LAW LLP (Dish Technologies L.L.C.)
6122 N 7th St Suite D
Phoenix, AZ 85014

ISSUE NOTIFICATION

The projected patent number and issue date are specified above. The patent will issue electronically. The electronically issued patent is the official patent grant pursuant to 35 U.S.C. § 153. The patent may be accessed on or after the issue date through Patent Center at https://patentcenter.uspto.gov/. The patent will be available in both the public and the private sides of Patent Center. Further assistance in electronically accessing the patent, or about Patent Center, is available by calling the Patent Electronic Business Center at 1-888-217-9197.

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Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment is 0 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Center (https://patentcenter.uspto.gov).

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APPLICATION #	RECEIPT DATE / TIME	ATTORNEY DOCKET #
18/069,450	**05/20/2024 05:45:19 PM Z ET**	**9401-00279**

Title of Invention

APPARATUS, SYSTEM, AND METHOD FOR MULTI-BITRATE CONTENT STREAMING

Application Information

APPLICATION TYPE	Utility - Nonprovisional Application under 35 USC 111(a)	PATENT #	11991234
CONFIRMATION #	8508	FILED BY	BLAKE SCHEFFEY
PATENT CENTER #	65600415	FILING DATE	12/21/2022
CUSTOMER #	70560	FIRST NAMED INVENTOR	DAVID F. BRUECK
CORRESPONDENCE ADDRESS	-	AUTHORIZED BY	Brett Carlson

Documents

TOTAL DOCUMENTS: 19

DOCUMENT	PAGES	DESCRIPTION	SIZE (KB)
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NPL3_IPRPetition_138.pdf	81	Non Patent Literature	555 KB
NPL6_IPRPetition_554.pdf	83	Non Patent Literature	748 KB
NPL2_MotionforJoinder_798.pdf	14	Non Patent Literature	927 KB
9401-00279_IDS_052024.pdf	5	Information Disclosure Statement (IDS) Form (SB08)	1234 KB
NPL4_MotionforJoinder_138.pdf	14	Non Patent Literature	907 KB

NPL5_IPRPetition_156_Final.pdf	76	Non Patent Literature	866 KB
NPL13_IPR2024-00045_ID.pdf	44	Non Patent Literature	530 KB
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NPL15_IPR2024-00047_ID.pdf	69406FA1D4B1AC911686FDB31172A427ABA53C850E055ABA0BAA251A51E6ACEBDF038A07283EEF93B846D053FAC5DFF46EF31F702224AB6E488F38C1C7804879
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NPL7_IPRPetition_555.pdf	4050D52D64B489FEFE4313BA59560FE8FB3C3931424944C07F31A0A2357FA7C1A7EDD6B0958DDD64C7B3F3A40DA200F1A1FF598290FE11AC5E14BE9AE5E00C21
NPL12_IPR2024-00044_ID.pdf	B53BC3A73783D488CBE745DBC3B9DBB847C19FBB6F9E1FD6409F171E4CD1C3DCAC0CD95599A741EF9D47BA36FBFB0FB16FB3460979BDFCA95954768EBE982A5C

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	18069450
Filing Date	2022-12-21
First Named Inventor	David F. Brueck
Art Unit	2454
Examiner Name	Chirag R. Patel
Attorney Docket Number	9401-00279

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
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	Attorney Docket Number	9401-00279

	1	fuboTV Media Inc. v. DISH Technologies L.L.C., "Petition for Inter Partes Review of U.S. Patent No. 11,677,798" dated May 13, 2024 (84 pages).	☐
	2	fuboTV Media Inc. v. DISH Technologies L.L.C., "Motion for Joinder Under 35 U.S.C. § 315(c), 37 C.F.R. §§ 42.22, and 42.122(b)" for U.S. Patent No. 11,677,798 dated May 13, 2024 (14 pages).	☐
	3	fuboTV Media Inc. v. DISH Technologies L.L.C., "Petition for Inter Partes Review of U.S. Patent No. 11,470,138" dated May 13, 2024 (81 pages).	☐
	4	fuboTV Media Inc. v. DISH Technologies L.L.C., "Motion for Joinder Under 35 U.S.C. § 315(c), 37 C.F.R. §§ 42.22, and 42.122(b)" for U.S. Patent No. 11,470,138 dated May 13, 2024 (14 pages).	☐
	5	fuboTV Media Inc. v. DISH Technologies L.L.C., "Petition for Inter Partes Review of U.S. Patent No. 10,757,156" dated May 17, 2024 (76 pages).	☐
	6	fuboTV Media Inc. v. DISH Technologies L.L.C., "Petition for Inter Partes Review of U.S. Patent No. 10,469,554" dated May 13, 2024 (83 pages).	☐
	7	fuboTV Media Inc. v. DISH Technologies L.L.C., "Petition for Inter Partes Review of U.S. Patent No. 10,469,555" dated May 13, 2024 (83 pages).	☐
	8	fuboTV Media Inc. v. DISH Technologies L.L.C., "Petition for Inter Partes Review of U.S. Patent No. 9,407,564" dated May 17, 2024 (85 pages).	☐
	9	fuboTV Media Inc. v. DISH Technologies L.L.C., "Petition for Inter Partes Review of U.S. Patent No. 10,951,680" dated May 13, 2024 (83 pages).	☐
	10	fuboTV Media Inc. v. DISH Technologies L.L.C., "Petition for Inter Partes Review of U.S. Patent No. 8,868,772" dated May 17, 2024 (85 pages).	☐
	11	Aylo Freesites LTD v. DISH Technologies L.L.C., IPR2024-00043, Patent No. 11,677,798, "Decision Granting Institution of Inter Partes Review" dated April 16, 2024 (49 pages).	☐

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	18069450
	Filing Date	2022-12-21
	First Named Inventor	David F. Brueck
	Art Unit	2454
	Examiner Name	Chirag R. Patel
	Attorney Docket Number	9401-00279

	12	Aylo Freesites LTD v. DISH Technologies L.L.C., IPR2024-00044, Patent No. 11,470,138, "Decision Granting Institution of Inter Partes Review" dated April 16, 2024 (44 pages).	☐
	13	Aylo Freesites LTD v. DISH Technologies L.L.C., IPR2024-00045, Patent No. 10,469,554, "Decision Granting Institution of Inter Partes Review" dated April 16, 2024 (44 pages).	☐
	14	Aylo Freesites LTD v. DISH Technologies L.L.C., IPR2024-00046, Patent No. 10,951,680, "Decision Granting Institution of Inter Partes Review" dated April 16, 2024 (48 pages).	☐
	15	Aylo Freesites LTD v. DISH Technologies L.L.C., IPR2024-00047, Patent No. 9,407,564, "Decision Denying Institution of Inter Partes Review" dated April 16, 2024 (25 pages).	☐
	16	Aylo Freesites LTD v. DISH Technologies L.L.C., IPR2024-00048, Patent No. 8,868,772, "Decision Denying Institution of Inter Partes Review" dated April 16, 2024 (24 pages).	☐
	17	Aylo Freesites LTD v. DISH Technologies L.L.C., IPR2024-00146, Patent No. 10,469,555, "Decision Granting Institution of Inter Partes Review" dated April 25, 2024 (46 pages).	☐
	18	Aylo Freesites LTD v. DISH Technologies L.L.C., IPR2024-00147, Patent No. 10,757,156, "Decision Denying Institution of Inter Partes Review" dated April 25, 2024 (25 pages).	☐

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Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	18069450
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	Art Unit	2454
	Examiner Name	Chirag R. Patel
	Attorney Docket Number	9401-00279

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

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☐ The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

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A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Brett Carlson/	Date (YYYY-MM-DD)	2024-05-20
Name/Print	Brett Carlson	Registration Number	39928

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
18/069,450	12/21/2022	DAVID F. BRUECK	9401-00279	8508

70560 7590 05/21/2024
KW LAW LLP (Dish Technologies L.L.C.)
6122 N 7th St Suite D
Phoenix, AZ 85014

EXAMINER
PATEL, CHIRAG R

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2454	

NOTIFICATION DATE	DELIVERY MODE
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The time period for reply, if any, is set in the attached communication.

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ipdept@dish.com
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APPLICATION NO.	ISSUE DATE	PATENT NO.
18/069,450	21-May-2024	11991234

KW LAW LLP (Dish Technologies L.L.C.)
6122 N 7th St Suite D
Phoenix, AZ 85014

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