$n[p] \in (0, N[p]-1)$ is the index of a particular representation of program p

$r[p, x]$ is the bit rate of representation x of program p during T

$q[p, x]$ is the quality of representation x of program p during T

FIGURE 1 depicts a first preferred embodiment of a Video-on-Demand server architecture 10 in accordance with the present principles for transmitting pre-encoded CBR and/or VBR audio/video programs over a fixed bandwidth channel 11 having a total channel capacity, C. The server architecture 10 includes a plurality of multirate stream generators 12_0, $12_1 \ldots 12_{P-1}$, where P is an integer greater than zero corresponding to the number of separate input streams. The stream rate generators 12_0-12_{P-1} each pre-code a corresponding one of the programs Program 0, Program 1...Program $P-1$ at a plurality of different bit rates. Stated another way, each multirate stream generator pre-codes the corresponding program to yield at least two or more different bit rate representations. A representation can include a particular stored encoded bit stream, or a combination of various portions of different encoded bit streams. A storage device 14, typically in the form of a single disc drive, a Redundant Array of Inexpensive Discs (RAID), or a plurality of RAIDs, serves to store the pre-coded representations generated by the multirate stream generators 12_0-12_{P-1}.

Each of the multirate stream generators 12_0-12_{P-1} generates control information for each time window T of for the corresponding one of Programs 0 to $P-1$, respectively. The control information for each time window T for each representation of each program includes an indication of the bit rate of that representation and a quality measure, such as the peak signal-to-noise ratio (PSNR) of the representation. A central statistical multiplexer ("stat mux") 16 receives the control information for each representation. At each successive time window T, the stat mux 16 selects a representation for each program to maximize the quality of the transmitted programs while maintaining the total bit rate at or below the total capacity C of the channel 11.

The lowest bit rate representation for each program should not exceed a prescribed value such that the sum of the lowest bit rates for all programs will not exceed the channel capacity for each interval T. In this way, at least one representation of each program can undergo transmission over the channel 11. Requiring the lowest bit rate representation for each program to have a peak bit rate of C/P or less can achieve this constraint. Other methods exist that meet the constraint $\sum_{p=0}^{P-1} r[p,0] \le C$ for all time windows T of all programs. Typically, advance knowledge does not exist as to when playback of particular programs will commence. Therefore,

enforcing capacity restraints becomes easiest by requiring that the bit rate limit of the lowest bit rate representation be the same for all time windows T of a particular program.

The process for the maximization of the overall combined quality can occur in several different ways. In all cases, the constraint $\sum_{p=0}^{P-1} r[p,n[p]] \leq C$ must remain met for all time windows T of all programs. A minimax approach can satisfy the constraint by choosing *n[p]* for each $p \in (0, P\text{-}1)$ to maximize the quality of the minimum quality program (i.e., minimizing the maximum distortion.)

The minimax approach can be implemented by sorting the control information for each representation of each program so that the quality and bit rate index increases monotonically increasing with the index. The change in bit rate for each step (referred to as the "delta (Δ)"bit rate) is then stored. The stat mux 16 begins with the lowest index for each program representation and computes the total capacity S. The stat mux 16 the selects the program representation at the lowest quality and checks if adding its delta bit rate to S exceeds C. If the addition of the representation does not exceed C, the index for that representation is incremented, and process is repeated. Once C is exceeded, the representation with the next to lowest quality is checked to see if adding its delta bit rate to S exceeds C. The process is repeated until no increment in any representation can be made without exceeding the channel capacity C. Alternatively, the total quality of all programs could be optimized by maximizing the sum of the individual program qualities which involves solving the following constrained optimization problem:

$$\max_{n[.]} \sum_{p=0}^{P-1} q[p,n[p]]; \text{ subject to } \sum_{p=0}^{P-1} r[p,n[p]] \leq C$$

It is also possible to optimize the product of the individual program qualities in the following manner:

$$\max_{n[.]} \prod_{p=0}^{P-1} q[p,n[p]]; \text{ subject to } \sum_{p=0}^{P-1} r[p,n[p]] \leq C$$

A weighted average can also be used, in order to provide different classes of service for different viewers.

The multirate stream generators 12_0-12_{P-1} can use several different methods, or a combination of methods to form multiple representations of each program. In all cases, a random access point, such as an intra-coded (I) frame should occur at the beginning of each time window T, for each representation, so that for each time window T a different representation can be

chosen without causing drift. Each representation can use either CBR or VBR coding as long as the capacity of the lowest bit rate representation meets the total channel capacity constraint.

In a first method, a multirate video encoder encodes each program at several different bit rates into several independent bit streams. Each different bit rate bit stream serves as a different representation. FIGURE 2 depicts an architecture 100 for carrying out this method. As seen in FIG. 2, a multirate video encoder 110 serves to encode a corresponding program to yield a plurality of different rate representations. A separate one of transport packetizers 112_0, $112_2 \ldots 112_{P-1}$ each packetizes a corresponding representation. The multirate encoding performed by the multirate encoder 110, and the packetization performed by the packetizers 112_0-112_{P-1} occurs once, not necessarily in real time, prior to storage in a storage device 140 similar in construction to the storage device 14 of FIG. 1.

Selection of the representations stored in storage device 140 for output in real time occurs in response to a signal received from a selector block 150. The selector block 150 identifies the stored representation for output in response to a request from the stat mux 160 for a particular representation. Upon receipt of the signal from the selector block 150, the storage device 140 supplies the selected packetized representations to the stat mux 160 for output.

In a second method, portions of the several different bit streams are combined to yield additional representations of a program. The presence of random access points at the same location in all bit streams of a program (as would naturally occur at scene changes) or the use of fixed group-of-pictures structures, permits the combination of compressed data from different bit rate streams at random access boundaries to form new representations. No need exists to store each representation independently, as long as the ability exists to generate each representation from the data that is stored. Consider the following example where T is one second, the data is coded at 30 fps, and I frames are inserted every 15 frames, yielding three different bit rate bit streams, designated as Bit stream 0, Bit stream 1, and Bit Stream 2, respectively. Each bit stream constitutes a separate representation. An additional representation can be formed which uses Bitstream 0 for the first 15 frames and Bitstream 1 for the second 15 frames, and so on.

Assuming alignment of the random access points with the transport packets, the server architecture 100 of FIG. 2 works well when the transport packetization occurs in advance. FIGURE 3 depicts a VoD server architecture 200 better suited when the random access points do not necessarily align with the transport packets. Referring to FIG. 3, VoD server architecture 200 includes multirate video encoder 210 for generating a plurality of different bit rate

representations for storage in a storage device 240 similar to the storage devices 14 and 140. The representations stored in the storage device 140 exist as un-packetized bit streams.

Selection of the representations stored in storage device 240 for output in real time occurs in response to a signal received from a selector block 250. The selector block 250, similar in nature to the selector block 150 of FIG. 2, identifies the stored representation for output in response to a request from a static mixer/multiplexer 260 for a particular representation. Upon receipt of the signal from the selector block 250, the storage device 240 supplies the selected packetized representations to the static mixer/multiplexer. A packetizer 212 packetizes the output stream of the static mixer/multiplexer 260 for output on the channel (not shown).

Representations also can be formed by switching between stored bit streams for non-reference pictures, such as for video codecs (not shown) that include pictures that are not used as reference pictures for predicting other pictures, such as MPEG-2 B frames or JVT non-stored pictures. Each non-reference picture can be selected from a different stored bitstream without affecting the quality of subsequently coded pictures, as the non-stored pictures are not used for prediction. Complete elimination of a non-reference picture in a representation can also occur. Each non-reference picture could be switched individually, or groups of non-reference pictures could be switched together, allowing for many possible total bit rate representations. The multirate stream signal generators 12_0-12_{P-1} of FIG. 1 can choose to limit the number of possible representations to send to the stat mux 16 of FIG. 1 to choose those with significant differences in quality and bit rate. It is not necessary for each representation to be independently stored in storage, but a table listing the location and length of each coded frame can be stored to simplify generation of the representation when needed. It is also possible to store multiple bit rate bit streams only for the non-stored pictures and only store a single version of the reference (I and P) pictures, which can significantly reduce storage requirements.

With the VoD server architectures 100 and 200 of FIGS. 2 and 3, respectively, the stat mux 160 and the static mixer/multiplexer 260 generate a bit stream corresponding to the selected representation. If individual pictures are not transport packet aligned, the architecture 200 of FIG. accomplishes transport packetization after the generation of the bit stream for a particular representation. Otherwise, the VoD server architecture 100 of FIG. 2 FIG. 2 will work well.

In accordance with another aspect of the present principles, scalable video coding can occur by the use of a scalable video encoder (not shown) to form a base layer and one or more enhancement layers. Any type of scalability that which employs the base layer for motion compensated reference picture prediction in order to avoid drift can be used, such as frequency

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scalability, FGS, SNR scalability or temporal scalability. The lowest bit rate representation corresponds to the base layer. The peak bit rate of the base layer must be such that when the bit rates of all programs' base layers are summed, the channel capacity C is not exceeded for each time window T. Other higher bit rate representations will correspond to the base layer plus some portion of the enhancement layer. This approach requires that the video decoder support the type of scalability used. The VoD server architecture 100 of FIG. 2 is used upon inclusion of an entire enhancement layer in a particular representation. The VoD server architecture 200 of FIG. 3 is used if portions of an enhancement layer are used in a representation.

For systems which use encryption for contents right management, the VoD server architecture 100 of FIG. 2 does not require any decryption or encryption in real time, as encryption is added to the transport packetization process done in non-real time and entire encrypted transport packets are stored and transmitted. The VoD server architecture 200 of FIG. 3 requires that encryption be performed along with transport packetization in real-time.

VoD programs generally include both audio and video. As audio bit rates are generally significantly lower than video bit rates and are also generally at a fixed bit rate, there is less advantage to be gained by selecting from different pre-encoded audio bit streams by the stat mux 16 and 160 of FIGS 1 and 2, and the static mixer/multiplexer 260 of FIG. 3. A user likely will find the switching of audio quality during the viewing of a single program disturbing. The total channel capacity C can be considered to be totally consumed by the video channel; assuming that a single bit rate audio stream is also sent for each program. Alternatively, the above-described methods can also be applied to audio, where multiple representations of audio programs with different bit rates and qualities can be generated.

A video player (not shown) that works with the VoD server architectures of the present principles will contain a video decoder (not shown) and some storage for buffering. For the particular program being received, the data can arrive at a non-uniform data rate, but with the requirement that the data corresponding to time unit T will arrive any time within the T time window. The video player must have the capability of buffering and delaying for T. An upper limit on the maximum bit rate that can be transmitted for a given representation of a program for a time window T can be pre-determined to limit the decoder complexity and decoder buffer size. The decoding buffer is generally a requirement of a video decoder, e.g. MPEG-2 levels sets buffer size particular requirements, and the combination of T and the bitrate may be chosen to meet it.

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Fast forward and fast reverse tracks for each program can also be stored at the VoD server. They can be stored at a single bit rate, or at several different bit rates, and allowed to adapt as is done for the normal play program.

Determination of the time window T length is based on several factors. T should be as large as possible to get the most statistical multiplexing gain, but small enough to constrain the delay at the video player for start-up and switching between normal play and trick play streams. T should be small enough to meet decoder requirements.

The foregoing describes a system and method for efficiently providing video on demand while maintaining bandwidth constraints of a fixed channel.

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CLAIMS

1. A method for transmitting a plurality of pre-coded programs having different bit rates across a fixed bandwidth channel, comprising the steps of:

generating at least two different bit rate representations of each program;

providing control information at each of a plurality of successive time windows T for each representation of each program, the control information for each successive window indicating a bit rate and quality measure for a representation of a corresponding program; and

during each time window T, selecting a representation for each program such to maximize the quality of the selected representations while not exceeding a total available capacity for the channel.

2. The method according to claim 1 wherein the step of generating at least two different bit rates representation further comprises the step of generating for each program a lowest bit rate representation having a peak bit rate not greater than C/P where C is the total channel capacity in time T and P is the total number of programs.

3. The method according to claim 1 wherein the step of providing the control information further comprises the step of establishing the peak signal-to-noise ratio (PSNR) as the quality measure embodied in the control information.

4. The method according to claim 1 wherein the selecting step further comprises the step of selecting a representation for each program which meets the constraint $\sum_{p=0}^{P-1} r[p, n[p]] \leq C$ for all time windows wherein:

C is the total channel capacity available in time frame T;

P is the total number of programs;

$p \in (0, P\text{-}1)$, is the index of a particular program;

$N[p]$ is the total number of representations of program p;

$n[p] \in (0, N[p] - 1)$ is the index of a particular representation of program p; and

$r[p, x]$ is the bit rate of representation x of program p during T

5. The method according to claim 4 further comprising the step of choosing each program's representation n[p] $\in$ (0, N[P]-1) to maximize the quality of the program p that had the minimum quality.

6. The method according to claim 5 further comprising the steps of:

(a) sorting the quality information for with the bit rate and quality measure monotonically increasing with an index value;

(b) storing each bit rate increment (delta) and quality value for each index value;

(c) beginning with a lowest index value, computing total capacity S for program representations selected thus far for such index value;

(d) selecting a program representation at a lowest quality measure;

(e) checking whether the bit rate increment of the selected program at the lowest quality, when added to the representations selected thus far, exceeds total channel capacity, and if not

(f) incrementing the index value; and

(g) repeating steps (c)-(f).

7. The method according to claim 1 wherein the selecting step further comprises the step of selecting the representation for each program such to maximize a sum of individual program qualities by solving $\max_{n[.]} \sum_{p=0}^{P-1} q[p, n[p]]$; subject to $\sum_{p=0}^{P-1} r[p, n[p]] \leq C$

wherein ,

C is the total channel capacity available in time frame T;

P is the total number of programs;

$p \in (0, P\text{-}1)$, is the index of a particular program;

$N[p]$ is the total number of representations of program p;

$n[p] \in (0, N[p] - 1)$ is the index of a particular representation of program p;

$r[p, x]$ is the bit rate of representation x of program p during T; and

$q[p, x]$ is the quality of representation x of program p during T.

8. The method according to claim 1 wherein the selecting step further comprises the step of selecting the representation for each program such to maximize a product of individual program qualities by solving

$$\max_{n[.]} \prod_{p=0}^{P-1} q[p,n[p]]; \text{ subject to } \sum_{p=0}^{P-1} r[p,n[p]] \leq C$$

where,

C is the total channel capacity available in time frame T;

P is the total number of programs;

$p \in (0, P\text{-}1)$, is the index of a particular program;

$N[p]$ is the total number of representations of program p;

$n[p] \in (0, N[p]-1)$ is the index of a particular representation of program p;

$r[p, x]$ is the bit rate of representation x of program p during T; and

$q[p, x]$ is the quality of representation x of program p during T.

9. The method according to claim 8 further comprising the step of applying a weighted average to provide different classes of service for different viewers.

10. A system for transmitting a plurality of pre-coded programs having different bit rates across a fixed bandwidth channel, comprising the steps of:

means for generating at least two different bit rate representations of each program;

means providing control information at each of a plurality of successive time windows T for each representation of each program, the control information for each successive window indicating a bit rate and quality measure for a representation of a corresponding program; and

means for selecting during each time window T a representation for each program such to maximize the quality of the selected representations while not exceeding a total available capacity for the channel.

11. The system according to claim 10 wherein the generating means and control information providing means collectively comprise:

a plurality of multirate stream generators, each associated with a corresponding one of the plurality of pre-coded programs.

12. The system according to claim 10 wherein the generating means and control information providing means collectively comprise:

a multirate video encoder for encoding at least two bit rate representations of each pre-coded program.

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13. The system according to claim 10 wherein the generating means and control information providing means collectively comprise:

a multirate video encoder for encoding at least two bit rate representations of each pre-coded program; and

a plurality of transport packetizers, each serving to packetize the bit rate presentations for each pre-coded program.

14. The system according to claim 10 wherein the selecting means includes a static multiplexer.

15. The system according to claim 12 wherein the selecting means comprises:

a static multiplexer; and

a transport packetizer for packetizing the selecting representation.

16. The system according to claim 10 wherein the selecting means generates for each program a lowest bit rate representation having a peak bit rate not greater than C/P where C is the total channel capacity in time T and P is the total number of programs.

17. The system according to claim 10 wherein control information providing means establishes quality measure in accordance with a peak signal-to-noise ratio (PSNR).

18. The system according to claim 10 wherein the selecting means selects a representation for each program which meets the constraint $\sum_{p=0}^{P-1} r[p, n[p]] \leq C$ for all time windows where:

C is the total channel capacity available in time frame T;

P is the total number of programs;

$p \in (0, P\text{-}1)$, is the index of a particular program;

$N[p]$ is the total number of representations of program p;

$n[p] \in (0, N[p] - 1)$ is the index of a particular representation of program p; and

$r[p, x]$ is the bit rate of representation x of program p during T.

19. The system according to claim 18 wherein the selecting means chooses each program's representation n[p] $\in$ (0, N[P]-1) to maximize the quality of the program p that had the minimum quality.

20. The system according to claim 10 wherein the selecting means selects the representation for each program such to maximize a sum of individual program qualities by solving:

$$\max_{n[.]} \sum_{p=0}^{P-1} q[p,n[p]]; \quad \text{subject to} \quad \sum_{p=0}^{P-1} r[p,n[p]] \le C$$

where,

C is the total channel capacity available in time frame T;

P is the total number of programs;

$p \in (0, P\text{-}1)$, is the index of a particular program;

$N[p]$ is the total number of representations of program p;

$n[p] \in (0, N[p]-1)$ is the index of a particular representation of program p;

$r[p, x]$ is the bit rate of representation x of program p during T; and

$q[p, x]$ is the quality of representation x of program p during T.

21. The system according to claim 10 wherein the selecting means selects the representation for each program such to maximize a product of individual program qualities by solving:

$$\max_{n[.]} \prod_{p=0}^{P-1} q[p,n[p]]; \quad \text{subject to} \quad \sum_{p=0}^{P-1} r[p,n[p]] \le C$$

where,

C is the total channel capacity available in time frame T;

P is the total number of programs;

$p \in (0, P\text{-}1)$, is the index of a particular program;

$N[p]$ is the total number of representations of program p;

$n[p] \in (0, N[p]-1)$ is the index of a particular representation of program p;

$r[p, x]$ is the bit rate of representation x of program p during T; and

$q[p, x]$ is the quality of representation x of program p during T.

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22. The system according to claim 10 wherein a weighted average is applied to provide different classes of service for different viewers.

ABSTRACT OF THE DISCLOSURE

A Video-on-Demand Server architecture (100, 200, 300) transmits a plurality of pre-coded programs having different bit rates across a fixed bandwidth channel (11). For each program, a generator (12_0-12_{P-1}, 110, 210) generates a plurality of different bit rate representations for each program. Each generator also provides control information at each of a plurality of successive time windows T for each bit rate representation. The control information provides a bit rate and a quality measure during each time window T. The control information enables a statistical multiplexer (16, 160, 260) to select a bit rate representation for each program during each time window T to maximize the quality of the selected representations while not exceeding the total available channel capacity.

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FIG. 1

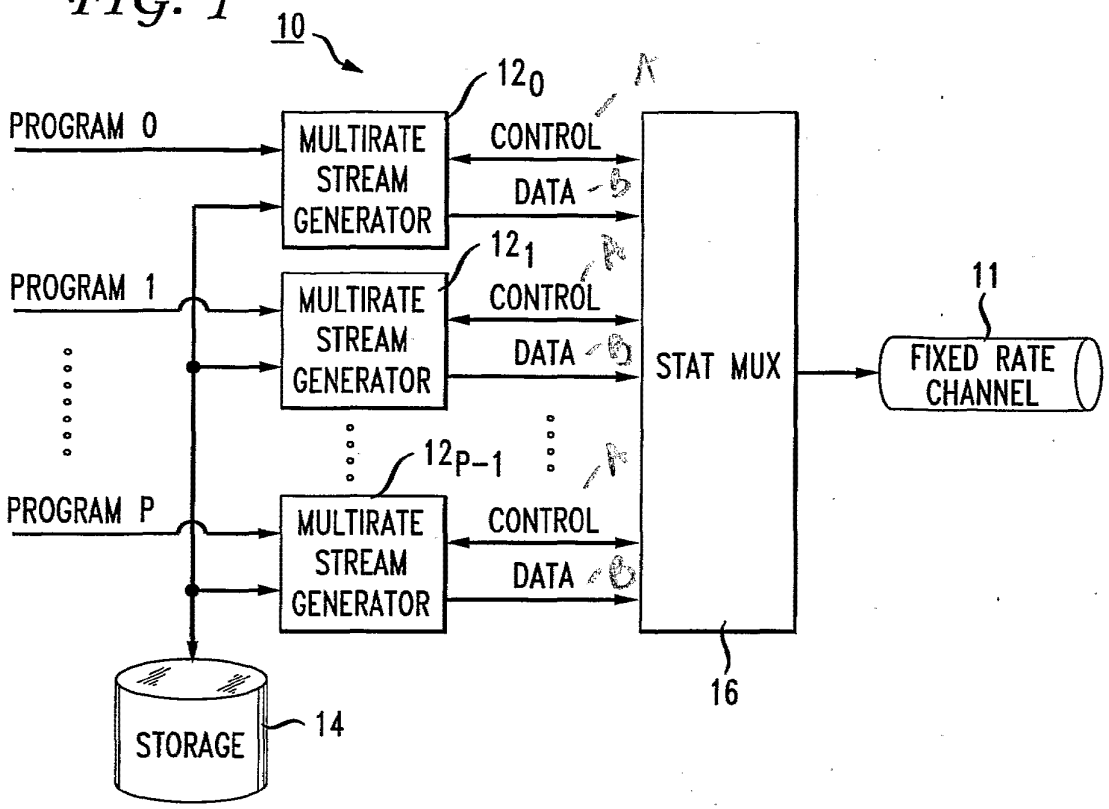

10
PROGRAM 0
PROGRAM 1
PROGRAM P
MULTIRATE STREAM GENERATOR
MULTIRATE STREAM GENERATOR
MULTIRATE STREAM GENERATOR
12_0
12_1
12_{P-1}
CONTROL
DATA
CONTROL
DATA
CONTROL
DATA
STAT MUX
11
FIXED RATE CHANNEL
16
STORAGE
14

FIG. 2

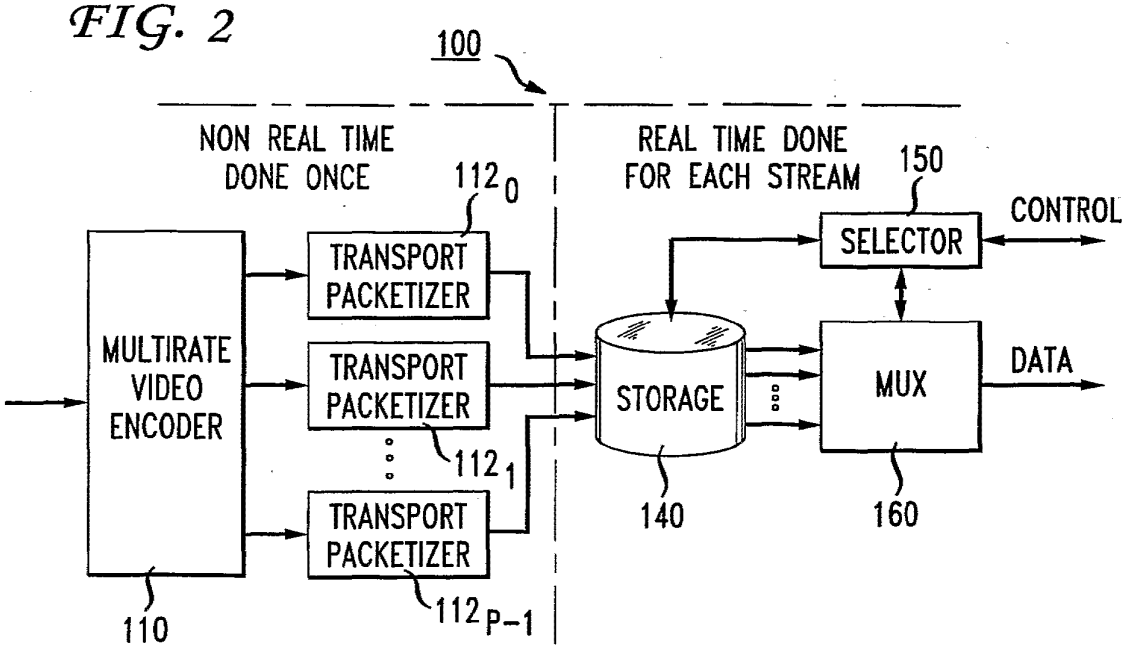
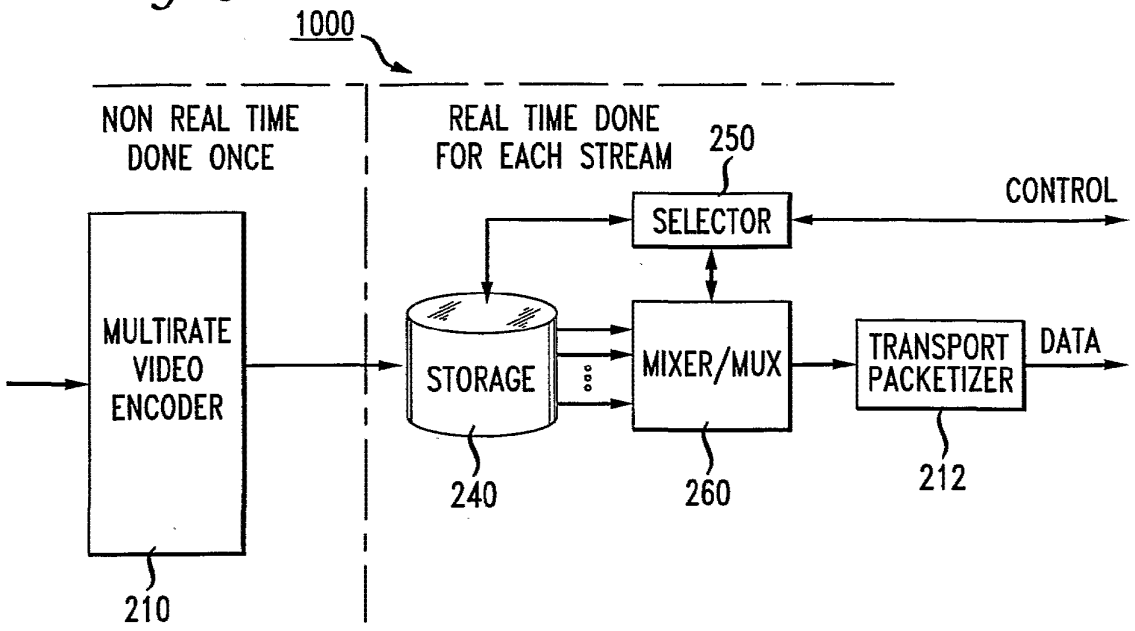

100
NON REAL TIME DONE ONCE
REAL TIME DONE FOR EACH STREAM
MULTIRATE VIDEO ENCODER
110
TRANSPORT PACKETIZER
TRANSPORT PACKETIZER
TRANSPORT PACKETIZER
112_0
112_1
112_{P-1}
STORAGE
140
150
SELECTOR
CONTROL
MUX
160
DATA

FIG. 3


1000
NON REAL TIME
DONE ONCE
REAL TIME DONE
FOR EACH STREAM
250
SELECTOR
CONTROL
MULTIRATE
VIDEO
ENCODER
STORAGE
MIXER/MUX
TRANSPORT
PACKETIZER
DATA
210
240
260
212

PCT
New International Application
Inventory of Unscannable or Missing Items

Serial Number

Check This Column if Item Is Present	Item	Check This Column if Item Is Missing on Filing
✓	Return Receipt Postcard	
	Check (amount $)	✓
✓	PCT EASY Diskette	
	DNA Diskette	
	Exhibit	
✓	Express Mail Label or Envelope	
	Applicant Supplied Priority Document	
	Other (specify)	XXXXXXXXXXXX XXXXXXXXXXXX XXXXXXXXXXXX XXXXXXXXXXXX XXXXXXXXXXXX
XXXXXXXXXXXX XXXXXXXXXXXX XXXXXXXXXXXX	Cover Letter	
XXXXXXXXXXXX XXXXXXXXXXXX XXXXXXXXXXXX XXXXXXXXXXXX XXXXXXXXXXXX	Other (specify)	

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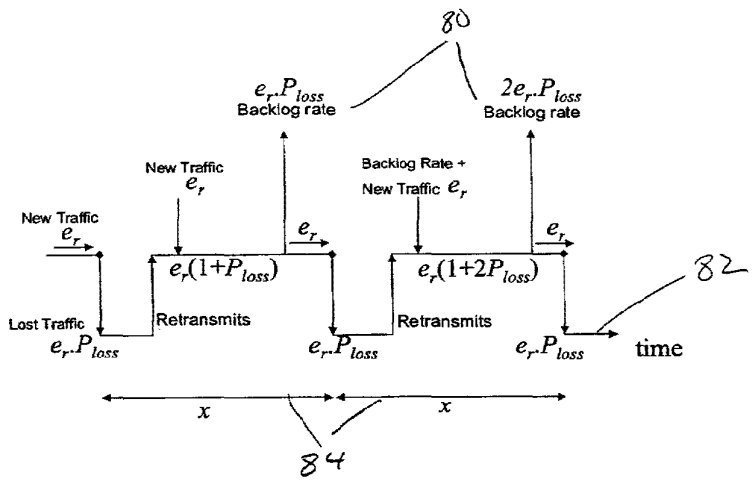
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(54) Title: APPARATUS AND METHOD FOR PREDICTABLE AND DIFFERENTIATED DELIVERY OF MULTIMEDIA STREAMING ON THE INTERNET



(57) Abstract: The inventive method detects network congestion which interferes with streaming of multimedia audio and video packets from and reacts to it and guarantees delivery of packets. The streaming of the multimedia audio and video packets is performed when a server process executing on a sending computing device sends the packets to a player process executing on a receiving computing device via a network, such as the Internet. The detection of the network congestion is performed by communicating configuration information including network parameters from a service manager via the network to the at least one sending computing device and to the at least one receiving computing device. The network congestion (80) is then confirming by transmitting and retracting network probes. At least one buffer management technique is executed to limit degradation in the streaming of the packets. The end of the network congestion is detected by transmitting and retracting said network probes and the rate of streaming of the packets is configured accordingly (82, 84).

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APPARATUS AND METHOD FOR PREDICTABLE AND DIFFERENTIATED DELIVERY OF MULTIMEDIA STREAMING ON THE INTERNET

TECHNICAL FIELD

This invention relates to the field of multimedia audio and video streaming on the Internet, and more particularly, to an apparatus and method for predictable and differentiated delivery of multimedia streaming on the Internet.

BACKGROUND OF THE INVENTION

Multimedia streaming involves broadcast of audio and video information from content providers called streaming servers or senders via the Internet to clients or receivers on user computing devices called streaming players. Real-time delivery of the multimedia streaming on the Internet is inherently uncontrollable and consequently unpredictable. When an Internet delivery path is congested, packets of multimedia streaming are typically dropped, thus causing degraded audio and video playback to be received by the streaming players. Typically, manifested forms of congestion can be classified into two types: instantaneous and sustained (longer-term). Instantaneous congestion is caused by random variations in the arrival patterns of packets of multimedia streaming at different Internet routers and switches, and due to the varying sizes of these packets.

These variations cause varying amounts of delay as the packets of multimedia streaming travel from the streaming server to the streaming receiver. If the delay accumulates beyond a certain point, the packets of multimedia streaming can get lost. This type of congestion typically causes sporadic delays and losses of over hundreds of milliseconds to a few seconds, and is hence referred to as "instantaneous congestion." In contrast, sustained congestion is longer-term and results during periods of excessive demand by the streaming players, e.g., demand for multimedia streaming from popular websites over the network paths on the Internet. During these periods, packet traffic surges can overwhelm the packet buffers in network routers, which are network traffic routing and forwarding computing devices, and packets of multimedia streaming can get

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lost in bursts. This is similar to a rush-hour traffic scenario on highways at peak hours. Unlike instantaneous congestion, sustained congestion can last from tens of seconds up to a few minutes.

It is well known that instantaneous congestion is an easy problem to solve. The client or the streaming player can buffer incoming packets of multimedia streaming for a short duration before playback. This reduces the effect of short-term delay between packets of multimedia streaming. Additionally, by requesting that a lost packet be immediately retransmitted, the streaming player can counter the loss of packets of multimedia streaming due to instantaneous congestion. Several existing streaming systems use these techniques, i.e., short-term buffering along with retransmits of lost packets, to isolate the streaming player from the effects of instantaneous congestion. Examples of these systems include the Robust-User Datagram Protocol (UDP) feature in the Real system from Real Networks and the NetShow 3.0 MediaPlayer from Microsoft.

The problem of sustained congestion is harder to solve. This difficulty relates to the fact that the Internet delivery lacks a uniform real-time control. Several standardization and research efforts have proposed ways to introduce such control; however, none have succeeded in creating a global Internet standard. The referred to standardization and research efforts include the following:

1. L. Kleinrock, "On Flow Control in Computer Networks", International Conference on Communications (ICC'78), pages 27.2.1-27.2.5;
2. D.E. Comer, R. S. Yavatkar, "A Rate-based Congestion Avoidance and Control Scheme for Packet Switched Networks", The 10th International Conference on Distributed Computing Systems, pages 390-397, 1990;
3. K.K. Ramakrishnan, R. Jain, "A Binary Feedback Scheme for Congestion Avoidance in Computer Networks", ACM Transactions on Computer Systems, Vol. 8, No. 2, May 1990, Pages 158-181; and
4. D. Mitra, "Asympotically Optimal Design of Congestion Control for High Speed Data Networks", IEEE Transactions on Communications, Vol. 40, No. 2, February 1992.

For example, the RSVP effort, described in Braden, R., Zhang, L., Berson, S., Herzog, S., and Jamin, S., "Resource Reservation Protocol (RSVP) - Version 1

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Functional Specification", RFC 2205, Proposed Standard, September 1997, seeks to add "quality of service" control within each network router and switch within the Internet. Another effort that seeks to create fast paths on the Internet is the "differentiated service" effort within the Internet Engineering Task Force (IETF) described in the following publications:

1) Nichols, K., Jacobson, V. and Zhang, L., "A Two-bit Differentiated Services Architecture for the Internet", Internet Draft, December 1997;
2) Ferguson, P., "Simple Differential Services: IP TOS and Precedence, Delay Indication, and Drop Preference", Internet Draft, November 1997; and
3) Clark, D. and Wroclawski, J., "An Approach to Service Allocation in the Internet", Internet Draft, July 1997.

The problem with these approaches is that they require structural changes throughout the Internet. This requirement assumes an explicit cooperation between various managers of the equipment comprising the Internet, which is an impractical assumption. Consequently, these efforts have stalled or are expected to have limited success. An alternative approach is to offer "adaptive applications". This approach proposes that application content be adapted based on the level of congestion. Methods based on this approach degrade the "experience" of an application in a controlled manner, but do not attempt to guarantee predictability or isolation from congestion effects. This approach is discussed in I. Busse, B. Deffner, H. Schulzrinne, "Dynamic QoS Control of Multimedia Applications based on RTP", May 30, 1995 and Real Networks, "White Paper on SureStream Technology", Available at http://www.real.com/devzone/library/whitepapers/surestrm.html.

What is needed is a "delivery framework" that will isolate streaming players from the effect of sustained congestion by providing a "predictable" delivery. Furthermore, there is also a need for a "differentiated streaming" framework that will provide for multiple levels of delivery isolation to the streaming players, without requiring structural changes in the Internet, as in K. Nichols et al., P. Ferguson and D. Clark, discussed above.

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SUMMARY OF THE INVENTION

The object of the present invention is to achieve a particular level of delivery isolation on particular streaming players. This level of delivery isolation may be based on factors like an importance "value" associated with particular streaming players, or the price the user of the streaming players are charged, etc. As an example, the streaming server may place specific streaming players in the high "value" category based on the demographic information on their owners, while other streaming players may be placed in the low "value" category.

Another object of the present invention is to ensure that the high value users of streaming players always receive consistent, predictable delivery of streaming content, even if there is an excessive user demand. If there is a situation of sustained congestion, wherein not all users can be satisfied, the content provider might want to ensure that the high value users are promised predictable delivery.

Accordingly, the present invention provides a method and an apparatus for predictable and differentiated streaming on the Internet. The system consists of software and random-access memory-based buffers installed at the streaming server and at the streaming players along with a service manager at a separate location. The method prescribes the manner in which the system is used to achieve predictable and differentiated delivery of streaming multimedia packets.

The invention is based on streaming multimedia packets between the software on the streaming server and the software on the streaming. The buffer sizes in the computing devices of the streaming player and of the streaming server are initialized based on the configuration information provided by the service manager software at the start of the execution of the inventive method. This configuration information includes:

a) the expected duration of sustained congestion periods,

b) the worst-case packet loss rate during the sustained congestion period,

c) the encoded bit-rate of streaming source information, and etc.

During the delivery of the streaming multimedia packets, the software on the streaming server relays the streaming packets to the software on the streaming player, which stores the packets in a playout buffer before playing them out. The playout buffer takes care of

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delay variation that may arise due to instantaneous congestion on the network path. In case of short-term losses caused by instantaneous congestion, the software on streaming player immediately requests the server-end software to retransmit the lost information.

Predictable Delivery Method

To deal with sustained congestion ("congestion") the invention incorporates the following method. The software on the streaming player uses estimation techniques based on probes to detect and confirm the onset of sustained congestion. Once the congestion status is verified, the streaming player software informs the streaming server software about this event. The streaming server software then modifies the manner in which it streams packets to the streaming player software. In particular, the streaming server software ensures that the transmission rate of packets never exceeds the encoded bit-rate of the streaming source. Furthermore, it gives preemptive priority to the retransmitted packets over new packets. This creates a backlog of new packets at one of the streaming server buffers.

Meanwhile, the streaming player software continuously monitors the status of received packets and detects the end of congestion through estimation techniques based on probes. Once the end of congestion is confirmed, the streaming player software informs the streaming server software about this event. The streaming server software then begins to stream its backlog of new packets to the streaming player software. The transmission rate of this stream is increased based on the estimation information from the streaming player software along with feedback obtained from other streaming players in the network. This rate is carefully selected to ensure that the network is not flooded back into congestion. The buffer sizing at the streaming player and at the streaming server is based on the configuration information and ensures that the user experiences an uninterrupted playback during sustained congestion. This assumes that the configuration information is the "worst-case" scenario. If the actual service parameters turn out to be worse than the configuration information, the streaming player software contacts the service manager after the service. The configuration information at the service manager is now updated in a persistent manner with the actual worst-case parameters.

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In one preferred embodiment, this update happens as follows. At the next service invocation, the buffers are sized based on the updated configuration information. The method thus automatically learns the worst-case behavior from the actual behavior of the network each time. Eventually, the method can guarantee a predictable delivery based on a non-interrupted playout in most cases. Various other embodiments are also possible, wherein the buffer size is fixed, but the encoding bit-rate of the stream is modified to choose the largest encoding bit-rate that leads to an uninterrupted playback.

Differentiated Streaming Method

The method for differentiated streaming involves identical operations as the predictable streaming method, except for the mechanism for streaming the backlog of packets from the streaming server software. For differentiated streaming, the streaming server software transmits the stream based on the "value" associated with the particular user, in addition to the information used for predictable streaming.

Accounting Delivery Service

Additionally, the methodology of the mentioned invention is utilized to offer the inventive method as an "accountable delivery service" to a large number of content providers, i.e., streaming servers, and users, i.e., streaming players. Such a service may deliver performance contract-based services to users of the streaming players on the Internet.

The service manager plays a central role in this service, by keeping and exchanging the state of several streaming players, delivery paths, and content providers/streaming servers in its database. The method of the present invention tracks the "actual" delivered viewing/listening experience of users of streaming servers by computing the delivery statistics including but not restricted to metrics that quantify "pauses or interruptions", "content throughput", and "content loss". In addition to the features of predictability and differentiation, the delivery service can also answer the question of "service feasibility". That is, at the beginning of a session, the service manager can estimate, based on the historical and instantaneous information, whether a

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particular user can receive an "expected quality experience." While the present invention does not describe the details of this service, it should be obvious to those skilled in the art to build such a service around the framework of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects and advantages of the invention will be apparent upon consideration of the following detailed description, taken in conjunction with the accompanying drawings, in which the reference characters refer to like parts throughout and in which:

Figure 1 is a schematic diagram of the devices and programs comprising the invention.

Figure 2 is a schematic diagram of the components of the devices utilized by the invention.

Figure 3 is a schematic diagram of the operation of the invention during normal streaming.

Figure 4 is a schematic diagram of the operation of the invention during congestion.

Figure 5 is a schematic diagram of the recovery scheduling operation of the invention after congestion.

Figure 6 is a diagram of the modeling the backlog operation of the invention during congestion.

Figure 7 is a state transition diagram for streaming player module (normal streaming).

Figure 8 is a state transition diagram for streaming server module (normal streaming).

Figure 9 is diagram of a congestion processing protocol at the streaming player module (during and after congestion).

Figure 10 is a diagram of an congestion processing protocol at the streaming server module (during and after congestion).

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DETAILED DESCRIPTION OF THE INVENTION

Architecture

The invention, shown in Figure 1, comprises at least one computing device 10 for executing a service manager process 12, at least one computing device 14 for executing streaming server process 16, and at least one computing device 18 for executing streaming player process 20. The service manager process 12 is shown as residing on the computing device 12 only for the clarity of presentation. It may be obvious to those skilled in the art that the service manager process 12 may reside on any computing devices 14 and 18. Furthermore, server processes 16 may be present on the computing devices 18 alongside player processes 20, and vice versa the player processes 20 may be present on the computing devices 14 alongside server processes 16. Each computing device 10, 14 and 18 are connected to a network 22 and establish data paths amongst each other. In the preferred embodiment, the network is the Internet.

The streaming server process 16 transmits a single multimedia stream to each streaming player process 20 and the streaming player process 20 receives that single multimedia stream. The streaming server process consists of three buffers:

a) Output buffer 24, used to transmit new packets from the server process 16 to the player process 20;

b) Backup buffer 26 , for maintaining temporary copies of the packets transmitted to the player process 20; and

c) Retransmit buffer 28, for maintaining retransmit requests received from the player process 20. The streaming player process 20 may comprise a player buffer 29.

Before a streaming session begins, the Service Manager process 12 downloads configuration information via the network 22 to both the computing device 14 for the use of the streaming server process 16 and to the computing device 18 for the use of the streaming player process 20. At the end of each streaming session, the configuration information on the computing device 10 is updated for the future use of the Service Manager process 12 via the network 22 by both the streaming server process 16 on the computing device 14 and the streaming player process 20 on the computing device 18.

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The computing devices 10, 14, and 18 may take the configuration of any computer ranging from mainframes and personal computers (PCs) to digital telephones and hand held devices, e.g., palm pilots™. In one illustrative embodiment of this invention shown in Figure 2, such computing devices may comprise a bus 30, which is connected directly to each of the following:

1. a central processing unit (CPU) 32;
2. a memory 34;
3. a system clock 36;
4. a peripheral interface 38;
5. a video interface 40;
6. an input/output (I/O) interface 42;
7. a communications interface 44; and
8. a multimedia interface 46.

The common bus 30 is further connected

1. by the video interface 40 to a display 50;
2. by the I/O interface 42 to a storage device 52, which may illustratively take the form of memory gates, disks, diskettes, compact disks (CD), digital video disks (DVD), etc.;
3. by the multimedia interface 46 to any multimedia component 56;
4. by peripheral interface 38 to the peripherals 58, such as the keyboard, the mouse, navigational buttons, e.g., on a digital phone, a touch screen, and/or writing screen on full size and hand held devices, e.g., a palm pilot ™;
5. by the communications interface 44, e.g., a plurality of modems, to a network connection 60, e.g., an Internet Service Provider (ISP) and to other services, which is in turn connected to the network 22, whereby a data path is provided between the network 22 and the computing devices 10, 14, and 18 (Figure 1) and, in particular, the common bus 30 of these computing devices; and
6. furthermore, by the communications interface 44 to the wired and/or the wireless telephone system 54.

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Normal Conditions

Turning now to Figure 3, the normal streaming operation is shown when there are either zero, i.e., no losses, or sporadic streaming losses, i.e., loss occurring due to instantaneous burst of streaming packets. The overall streaming sequence works as follows. Packets streamed from the streaming server process 16 are queued up in the streaming server output buffer 24 for transmission. The server process 16 is responsible for transmitting streaming packets 70 to the computing device 18 executing the player process 20. Periodically, this process 16 checks the output buffer 24 and the retransmit buffer 28 to determine if there are streaming packets 70 awaiting transmission or any requests form the player process. Any remaining streaming packets in the output buffer 24 are then transmitted. If retransmission requests are found, any streaming packets 70 requested for retransmission and found in the backup buffer 26 are transmitted. When streaming packets 70 are transmitted, a temporary backup copy of the transmitted streaming packets 70 is kept in the backup buffer.

The streaming player process 20 receives the streaming packets 70 and stores them at the tail-end of the player buffer 29. Periodically after a user-defined interval, the player process 20 examines the received streaming packets 70 to see if any streaming packets 70 are missing. If packets are missing, the player process 20 sends a request 72 to the server process 16 to retransmit the missing packets. After assuring that all the streaming packets 70 are received, the received streaming packets 70 are forwarded from the head-end of the player buffer to the streaming player process 20.

Congested Conditions

The invention detects congestion early on, and then may take steps so that the impact of congestion on the stream is minimized. A correctly configured framework can keep a stream completely transparent of sustained congestion, thus providing an effect equivalent to a "reservation." Two principles are at the basis of this framework, detection/reaction to congestion and congestion recovery.

1. Detecting and reacting to congestion

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The invention detects congestion through probes launched by the player process 20. The probes are discussed in detail later. Once congestion is confirmed, the server process 16 reacts by using a technique called "constant bit-rate emulation." This name derives from the fact that the server process 16 tries to maintain a constant upper bound on the rate at which the streaming packets 70 are streamed to the player process 20. Typically, the upper bound is set equal to the encoding bit rate of the stream. In effect, the server process 16 emulates a constant bit-rate by substituting new server packets with packets that have been requested 72 for retransmission. Please recall that in congestion, the server has a large number of retransmit requests 72 issued from the player process 20. Figure 4 shows the flow of streaming packets 70 during this congestion situation. Two important reasons motivate the constant bit-rate emulation method:

a) The method demonstrates a "network-friendly" yet efficient behavior. The method is network-friendly, since it conserves bandwidth during congestion by lowering the upper bound of its streaming transmission rate. Additionally, the method is efficient for the following reasons. First, the upper bound on the transmission rate is set equal to the maximum encoding bit-rate of the source stream; this is not a restrictive setting. Unlike other schemes that voluntarily reduce the source rate during congestion, the present invention only reduces the transmission rate by the amount of incurred loss. This decision has an important implication in practice. Most practical congestion-processing algorithms will incur errors and delays in estimating and reacting to the start of congestion or end of congestion. Consequently, there will be temporary periods in which these algorithms "think" that the network is congested, when in practice, the network has cleared out of congestion. In situations like this, estimation errors do not degrade the streaming throughput. In fact, the invention delivers a throughput better or equal to the throughput of any other scheme, if there is no loss of streaming packets 70.

b) Assuming most connections sharing the network with streaming are using the Transmission Control Protocol (TCP), the constant bit-rate of the invention in congestion allows the TCP traffic on the same path to accurately sense the available bandwidth (most Internet or Web traffic uses TCP). An alternative design with

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adapting bit-rate would confuse most other TCP connections and cause each to keep oscillating their TCP windows. If all TCP connections maintain a steady window-size, the performance of the network is much smoother in congestion. This behavior can drain out the congestion faster and reduce the estimation errors.

2. Detecting End-of-Congestion and Recovery from congestion

The invention detects the end of congestion through probes launched by the player process 20. Once the player process 20 confirms that congestion is over, the server process 16 enters a phase called "recovery scheduling". Figure 4 shows a recovery scheduling after congestion. To understand this phase, recall that in the previous state of congestion, the server transmits packets at a constant rate. By substituting new packets with older lost packets, the server is in effect creating a backlog of new packets in its output buffer. The idea in recovery scheduling is to exhaust the substantial backlog that may build up at the server output queue. Clearly, this backlog must not be cleared by flooding the network. Such action may cause significant losses in the intermediate switch buffers. In addition, if thousands of streams of packets 70 flood the backlog at the same time, this may cause certain network points to get congested again. Recovery scheduling is a procedure that configures the rate of streaming the backlog based on the network parameters. Additionally, recovery scheduling can also take into account the "premium" placed on the particular player process 20. The latter consideration allows the server process 16 to stream backlog of streaming packets at different priorities. "Higher value" users can receive backlog sooner than "lower value" users. This is the basic principle behind differentiated streaming.

Buffer Design

As described previously, the configuration information is downloaded to the computing devices 14 and 16 at the beginning of each streaming session. This configuration information includes the following parameters:

(1) Worst-case duration of congestion, $c*x$, where x is a sampling or retransmission interval, and c is a number of sampling intervals in a congestion period.

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(2) Worst-case of loss of streaming packets 70 during congestion defined by P_{loss}

(3) Encoding bit-rate of the stream of streaming packets 70 defined by e_r

(4) Averaged and minimum service rate, SR_{avg} and SR_{min}. This is the rate at which streaming packets 70 are actually transferred from the server process 16 to the player process 20. SR_{min} is the minimum rate across the path via the Internet 22 from the server process 16 to the player process 20.

(5) Path bottleneck link bandwidth B_{min} and the hop link capacities, where B_{min} is the minimum physical bandwidth across all the hops, i.e., the routing devices between the server process 16 and the player process 20.

The parameters indicated in the list above may be obtained through historical measurements of the relevant values and through measurements made on streaming packets 70 at the computing device 14 of the server process 16. The parameters are in turn used to design the sizes of the buffers 24, 26, 28 and 29 of server process 16 and the player process 20. One preferred embodiment of achieving this is described immediately below. That embodiment ignores the upper bounds limits on the buffer sizes related to the available random-access memory 34 (Figure 2) in the computing devices 14 and 18.

Player Buffer-size (b_c)

The buffer on the computing device 18 used by the streaming player process 20 plays out the streaming packets 70 at the maximum rate of e_r bits per second. During sustained congestion, the packet loss is approximately P_{loss}, and the maximum transmission rate from the server, as explained above is e_r. It follows that the rate of the player buffer 29 fill rate equals to $e_r * (1 - P_{loss})$ bits per second. Thus, the net drain on the player buffer 29 proceeds at the rate of $e_r * P_{loss}$ bits per second. To prevent the player buffer 29 from draining out completely within the congestion period $c * x$, the buffer-size of the player buffer 29 should satisfy the constraint defined as:

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$$\frac{b_c}{e_r * P_{loss}} \geq c * x \quad \text{or} \quad b_c \geq c * x * e_r * P_{loss} \qquad \text{(Equation 1)}$$

Streaming Server Output Buffer-size (b_o)

Recall that the streaming server output buffer holds the backlog of new packets created during the congestion period. Consequently, the size of this buffer is dictated by the worst-case amount of backlog during the congestion period. To calculate the worst-case backlog of the streaming packets 70, a simple model may be built up. Figure 6 shows the approximate amount of backlog as a function of time 82 during sustained congestion. As indicated, the backlog rate 80 after two retransmission intervals 84 is $2 * e_r * P_{loss}$. By extension, after c retransmission intervals 84, the backlog rate 80 will be $cx * e_r * P_{loss}$. This establishes the constraint on the size of the output buffer 14 (Figure 1) in the memory 34 (Figure 2) of the computing device 14 (Figure 1) executing streaming server process 16 (Figure 1).

$$b_o \geq c * x * e_r * P_{loss} \qquad \text{(Equation 2)}$$

Server Backup Buffer-size (b_{backup})

The backup buffer 26 (Figure 1) holds temporary copies of the server packets that have been transmitted to the player process 20 (Figure 1). The copies must be held until the server is sure that the packets have been successfully received in the player buffer 29 (Figure 1). To estimate the size of this backup buffer 26 (Figure 1) again, an operational model is built. First, the transmission rate in packets per seconds is defined as R_p. At the start of the first retransmit 84, the approximate rate of loss of the streaming packets 70 (Figure 3) is $P_{loss} * R_p$. Assuming the loss affects new as well as retransmitted streaming packets 70 (Figure 3) equally, the approximate rate of loss for older unsuccessful streaming packets 70 (Figure 3) at the second retransmit 84 is $P_{loss}^2 * R_p$. Supposing now that the number of retransmits that will reduce the loss rate for older

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packets to a negligibly small number, e.g., 0.1 packets for every retransmission interval is defined by m. This implies that:

$$P_{loss}^{m} * R_p \leq \frac{0.1}{x}, \quad \text{or that} \quad m \geq \frac{\log\left(0.1/R_p * x\right)}{\log P_{loss}}$$

Alternatively, if s is the packet size, the above equation may be expressed as:

$$m \geq \frac{\log\left(0.1 * s/e_r * x\right)}{\log P_{loss}}$$

The minimum required buffer size may be defined as equal to $m * x$. Consequently, the size constraint of the backup buffer 26 (Figure 1) is

$$b_{backup} \geq m * x \quad \geq x * \frac{\log\left(0.1 * s/e_r * x\right)}{\log P_{loss}} \qquad \text{(Equation 3)}$$

The detailed operational method underlying the invention is captured through a protocol called "Streaming Congestion Protocol" (SCP). In the section below the SCP sequences during different phases of streaming are described. Figures 6 and 7 show the detailed operational sequence at the streaming server process 16 (Figure 3) and the streaming player process 20 (Figure 3) during normal streaming of the streaming packets 70 (Figure 3). The operational sequences are described with the help of state diagrams. A state diagram shows various states and transitions between states. Each state captures a specific operational state, and the transitions between states capture the events that cause the operational states to change. Figure 7 shows the state diagram of events at the streaming server process 16 (Figure 1). Figure 8 shows the corresponding state diagram at the streaming player process 20.

Processing during and after congestion

Please refer to Figure 9, by default, the streaming player process 20 is in a normal state 100. The player process 20 may keep a track of the packet loss of a received stream at a periodic interval that may be user determined. If the amount of loss exceeds a

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threshold, e.g., Threshold1, across a time-window of some number of seconds which may also be user determined, e.g., TW1, the player process 20 moves into the Likely Congestion state 102. At this point, the streaming player process 16 (Figure 1) launches congestion probes to determine whether the congestion symptoms are verified. These probes form a part of a test called confirm congestion test. If the test indicates that congestion is confirmed, the process moves to a Congestion Confirmed state 104. Immediately, the streaming player process 20 contacts its server counterpart and informs it about the new state change along with some other relevant information.

Note that the transition from a Likely Congested state 102 to Congestion Confirmed State 104 can happen in two other ways. First, the player process 20 may actually receive a Remote Congestion Confirmed report in state 106 from its server process 16 (Figure 1) indicating that some other player process 20 on a related network path is in the Congestion Confirmed state. If this happens, the player immediately moves to the Congestion Confirmed State 104 itself. If the player process 20 has already started conducting congestion probes before this notification, the player process 20 may halt them at the instant it receives the notification. Alternatively, the player process 20 may receive a Local Congestion Confirmed report in state 102 reporting that some other local player process 20 on the same streaming player module has verified congestion. If the Remote or local Congestion Confirmed reports have verified congestion within a past time-window not exceeding the time defined as Tcc, the player process 20 moves to a confirmed congestion state 104.

Once the streaming player process 20 (Figure 1) enters the congestion confirmed state 104, it periodically monitors the loss of the received stream of streaming packets 70 (Figure 3). If the packet loss is less than a second user defined threshold, e.g., Threshold2, across a second user defined time-window, e.g., TW2 seconds, the player process 20 enters the likely end-of-congestion (EOC) state 106. At this point, the player process 20 launches an EOC probe test that either confirms or invalidates the EOC decision. If the EOC probe test confirms congestion, the streaming player process 20 enters the EOC state 108 and sends an EOC report 110 to its server process 16 (Figure 1) counterpart. With this transition, the process re-enters the normal state 100. Note that

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during transitions from the EOC state 110 back to the Normal State 100, the streaming player process 20 also needs to continually process the arriving packets in step 120 (Figure 7), check and request for retransmission of missing packets in step 122 (Figure 7), and forward packets to the streaming player for playback in step 124 (Figure 7). These activities are indicated in Figure 7 and are not shown in Figure 9 for purposes of clarity.

Figure 10 shows the SCP state-diagram of the server process 16. After initialization, the server process 16 enters the normal state 130. If the server process 16 receives a report from its streaming player process 20 (Figure 1) indicating congestion, the server moves to the Confirmed Congestion or Confirmed Congestion State 132. At this point, the server process 16 shares the Confirmed Congestion status information with other server processes 16 running on the same computing device 14 (Figure 1) in the Propagate Confirmed Congestion state 134, and potentially also from other computing device 14 (Figure 1) through interaction with the service manager 12 (Figure 1) via the network 22 (Figure 1). The idea behind this is to have selected server processes report the congestion to their player process so that these player processes can avoid doing the Confirmed Congestion probing test. This cuts down on the congestion reaction time and significantly cuts down the probing traffic. In general, each server process that receives the Confirmed Congestion status in the Receive the Confirmed Congestion status state 140 from other server processes 16, first determines whether the Confirmed Congestion status is relevant to its target player process 20 (Figure 1). If this is the case, the server processes notify their player process 20 (Figure 1). Notification is done through a special signaling scheme involving reliable transport protocol (RTP) messages, as discussed in Schulzrinne, Casner, Frederick, Jacobson, "RTP: A Transport Protocol for Real-time Applications", RFC 1889, Internet Engineering Task Force.

The streaming server process 16 will then make transitions from the Confirmed Congestion State 132. Starting with the Confirmed Congestion state 132, the server process 16 transmits streaming packets 70 (Figure 3) at a constant bit-rate. The server process 16 moves to the Recovery Scheduling State 136 as soon as it receives an End-of-congestion or EOC report from the player process 20 (Figure 1) targeted for the reception of

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its content. Thereafter the server process 16 changes its mode of transmission, using recovery scheduling to drain its backlogged output buffer 24 (Figure 1) in an intelligent way. As soon as the backlog is over, the server process 16 moves back to the normal state 130.

While in the Normal State 130 the server process 16 may receive and filter information from other server processes 16 by entering the Receive Confirmed Congestion State 140. It may also notify the player processes 20 (Figure 1) about the confirmed congestion status through the in-band RTP signaling, by entering the Confirmed Congestion Notification state 138 from where the process 16 will return to the Normal state 130.

The server process 16 also needs to continually process the departing packets in step 150 (Figure 8), check and process the requests for retransmission of missing packets in step 152 (Figure 8), and backup packets to the backup buffer 26 (Figure 1) for playback. These activities are indicated in Figure 8 and are not shown in Figure 10 for purposes of clarity.

Recovery scheduling algorithm

Supposing that the server process 16 (Figure 1) streams of streaming packets 70 (Figure 3) are classified into K number of priority classes. Class 1 being the highest priority and class "K" being the lowest priority. Each priority class "j" is associated with a weighting function α^j, where $0 < \alpha^K < \alpha^{K-1} < .. \alpha^j < .. < \alpha^1 = 1$. Considering the server process 16 (Figure 1) with priority equaling to "j", the rule for transmission rate e_t of this process is:

$$e_t = \min(\alpha^j \times SR_{min}, \alpha^j \times \frac{B - \lambda_{other}}{\sum_{i=1}^{i=K} \alpha^i n^i})$$

(Equation 4)

In equation 4, all the terms are measured at the service bottleneck hop between the computing device 14 executing the server process 16 and the computing device 18 executing the player process 16. B is the bottleneck link capacity at the bottleneck hop.

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λ_{other} is the aggregate packet rate carried at the hop from traffic not utilizing the inventive method. This rate can be estimated by obtaining the aggregate packet rate of the streaming packets 70 (Figure 3) of the inventive method λ_{SME} from the service manager, and using the fact that $\lambda_{other} = B \times \rho - \lambda_{SME}$, where $\rho = 1 - \frac{SR_{\min}}{B}$ is the utilization of the bottleneck hop. The parameter n^i is defined as the number of priority "i" streams carried at the bottleneck hop. The hop is a section of a network between two network-computing devices such as routers. This parameter may be obtained from the service manager 12 (Figure 1). The logic behind this equation is as follows. The first term indicates that the new transmission rate should be set equal to the minimum service rate along the path, in order to recover from the backlog. The second term takes into account the result of increasing the transmission rate on the utilization at the bottleneck hop. In other words, since the maximum utilization can be 100%, each computing device 14 executing server process 16 must carefully weigh the effects of increasing the transmission rate. The best rate is the maximum rate that does not congest the bottleneck bandwidth during recovery. Hence the min operator. Finally, the priorities within the equation 4 provide for differentiated streaming.

Congestion Estimators

Earlier on, we described the congestion estimation tests as part of the SCP algorithm. In principle, congestion can be estimated in a variety of ways, and the invention is not restricted to any one particular method of congestion estimation. A particular embodiment of the invention for estimating congestion based on a mix of passive and active probes will now be described. This method comprises a set of rules configured around the results of the probes. A specific congestion test e.g., an end of congestion test or a confirmed congestion test mentioned in earlier sections, combines these rules in a particular way.

The following are some of a variety of methods that may be used to compute the bottleneck bandwidth on a path between the streaming player 20 (Figure 1) and the

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streaming server 16 (Figure 1). These methods are shown here for exemplary purposes only and not to indicate that only these methods must be used with the present invention.

Capacity Probe

This method is described in detail in Van Jacobson, "pathchar - A tool to infer characteristics of Internet paths", MSRI, April 21, 1997; and R. L. Carter and M.E. Crovella, "Measuring Bottleneck Link Speed in Packet-switched Networks", TR-96-006, Boston University Computer Science Department, March 15, 1996. This method is initiated by the player process 20 (Figure 1) at various stages of a streaming session. The steps of this exemplary method are as follows:

1. Do a traceroute and get hop identities marked by IP addresses.
2.

a) For every hop from one onwards, send a series of ICMP timestamp requests (type 13) from the player to the hop. Packet sizes of queries are changed in steps of 1024, 512, 256, 128, and 64, where each queries are sent out with a spacing of 3 seconds between them.

b) For every hop i between the player and the server, the player must record the ICMP timestamp response (type 14) and compute the time difference between the hop i transmit time t_i and the player receive instant t_1.

c) Denote the time difference by $\tau_{i1} = t_i - t_1$.

d) Take four measurements for timestamp differences by varying packet size through five values. Discard the minimum and the maximum, and take average of the remaining two. Let s' and s'' denote the packet sizes of two selected queries to hop i. Let $\tau_{i1'}$ and $\tau_{i1''}$ denote the measurements for the respective packet sizes.

e) Calculate $X_{i1} = \frac{\tau_{i1'} - \tau_{i1''}}{s' - s''}$

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$$B_{i,i-1} = \frac{1}{X_{i1} - \left(\sum_{k=1}^{i-2} \frac{1}{B_{i-k,i-k-1}} \right)}$$

It can be proved that link capacity can be computed recursively.

The path bottleneck bandwidth $B_{min} = \min_i B_{i,i-1}$. (Equation 5)

Service Rate Probe

The "Service Rate probe" computes the approximate service rate of transferring packets between the server and the player, as discussed in Van Jacobson, "pathchar - A tool to infer characteristics of Internet paths", MSRI, April 21, 1997; and R. L. Carter and M.E. Crovella, "Measuring Bottleneck Link Speed in Packet-switched Networks", TR-96-006, Boston University Computer Science Department, March 15, 1996. The minimum service rate is the least service rate on the path, while the average service rate is the "expected" service rate on the path. . The steps of this exemplary method are as follows:

1. Obtain the hop list through traceroute. Suppose there are n-1 hops between the player and the server.
2. Periodically, the player initiates a cycle. In each cycle, the player sends n-1 queries, each spaced by ¼ second. The player forms timestamp differences between query responses from consecutive hops. The results are sent back to the server.
3. The server uses results from several cycles along with the link capacities to calculate the service rate.
   a) First, the server calculates $\tau_{m,m-1}^{min} = min(\tau_{m,1} - \tau_{m-1,1})$ where the min operator works over all collected cycle results. We approximate $\tau_{m,m-1}^{min}$ to be the base-line delay between node m and node m-1.
   b) Denote the maximum queuing delay between node m and node m-1 by $q_{m,m-1}^{max}$, where node is a computing device, e.g., a computer or a router connected to the network.

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c) Then, $q_{m,m-1}^{max} = max\left(\tau_{m,m-1} - \tau_{m,m-1}^{min}\right)$

d) Denote the average queuing delay between node m and node m-1 by $q_{m,m-1}^{avg}$.

e) Then, $q_{m,m-1}^{avg} = avg\left(\tau_{m,m-1} - \tau_{m,m-1}^{min}\right)$

Finally, the minimum service rate is:

$$SR_{m,m-1}^{min} = \frac{s}{\frac{s}{B_{m,m-1}} + q_{m,m-1}^{max}},$$

and the average service rate is:

$$SR_{m,m-1}^{avg} = \frac{s}{\frac{s}{B_{m,m-1}} + q_{m,m-1}^{avg}} \qquad \text{(Equation 6)}$$

Congestion Detection Rule (CC Test)

A robust but responsive congestion detection mechanism is an essential part of the inventive method. It is important to respond quickly to congestion; this can reduce the congestion period and hence make it easier for the recovery scheduling to do its job in a shorter period of time. Ultimately this can allow the method to work with a reduced buffer size and hence a reduced connect lag. It is equally important to robustly distinguish a sustained congestion condition. False detection can lead to reduced throughput and performance. Recall that the inventive method treats sustained congestion by reducing the throughput of the newer packets, so that the throughput of older retransmitted packets is maximized.

The present invention uses the following congestion detection rule:

1. Packet losses exceeding a threshold for a consecutive time-window of duration T_s. T_s is set to 10 seconds by default.
2. If condition 1 is triggered, three short service rate probes are sent, spaced 2 seconds apart, from the player to the SR_{min} hop. Responses are averaged to form

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SR_{avg}.

The player process 20 (Figure 1) computes the expected utilization $\rho = 1 - \frac{SR_{avg}}{B}$. If condition 1 is satisfied and the utilization from condition 2 is more than a specified utilization threshold, e.g., 95%, the player process 20 (Figure 1) declares sustained congestion (Confirmed Congestion), and asks the server to enter the constant bit-rate emulation mode. An alternative method may consists of a simple rule where if packet losses exceed a threshold for N_1 consecutive sampling time-windows, the player process 20 (Figure 1) declares sustained congestion and asks the server to enter the constant bit-rate emulation mode. By default, N_1 is set to 1, and time-window is set equal to 1 second.

End of Congestion Rule (EOC Test)

The end of congestion rule is analogous to the congestion detection rule:

1. No packet losses for a consecutive time-window of duration T_e. T_e is set equal to 10 seconds by default.
2. If condition 1 is triggered, three short service rate probes are sent, spaced 2 seconds apart, from the player to the SR_{min} hop. Responses are averaged to form SR_{avg}.

   The player computes the expected utilization $\rho = 1 - \frac{SR_{avg}}{B}$.

If condition 1 is satisfied and the utilization from condition 2 is less than a specified threshold, e.g., 90%, the player declares sustained congestion to be over, and asks the server to transition to the state of recovery scheduling. An alternative method may consists of a simple rule where if in a state of sustained congestion, no packet losses are manifest for N_2 consecutive sampling time-windows, the player declares sustained congestion to be over, and asks the server to transition to the state of recovery scheduling. By default, N_2 may be set equal to five, and the sampling time-window is set equal to 1 second.

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Thus, an apparatus and method for predictable and differentiated delivery of multimedia streaming on the Internet is provided. One skilled in the art will appreciate that the present invention can be carried out in other ways and practiced by other than the described embodiments, yet not departing from the spirit and essential characteristics depicted herein. The present embodiments therefore should be considered in all respects as illustrative, and the present invention is limited only by the claims that follow.

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CLAIMS

Having thus described our invention, what we claim as new, and desire to secure by Letters Patent is:

1. A method of streaming of multimedia audio and video packets from at least one sending computing device to an at least one receiving computing device via a network, said method comprising the steps of:

a) at a start of said streaming communicating configuration information from a service manager via the network to both an at least one sending computing device for use by an at least one server process and an at least one receiving computing device for use by an at least one player process, said at least one sending computing device comprising an at least one retransmit buffer, an at least one output buffer, an at least one backup buffer and said at least one server process, said at least one receiving computing device, comprising an at least one player buffer and an at least one player process;

b) queuing same packets in the at least one output buffer and to the at least one backup buffer;

c) determining if there are packets in the at least one output buffer and transmitting the packets from the at least one output buffer to the at least one receiving computing device via the network;

d) receiving the packets on the at least one receiving device and storing them in the at least one player buffer;

e) determining if there are omissions in the packets stored in the at least one player buffer and forwarding retransmission requests to the at least one sending computing device and storing them in the at least one retransmit buffer; and

f) determining if there are said retransmit requests in the at least one retransmit buffer and transmitting the packets from the at least one backup buffer to the at least one receiving computing device via the network.

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2. The method of claim 1 wherein, the network is Internet.

3. The method of claim 2 wherein, a size of the at least one player buffer is $\geq c*x*e_r*P_{loss}$, where c is a number of sampling intervals in a congestion period, x is a sampling or retransmission interval, $c*x$ is a worst-case duration of congestion, e_r is an encoding bit-rate of a stream of the packets and P_{loss} is a worst case of loss of the packets.

4. The method of claim 3 wherein, a size of the at least one output buffer is $\geq c*x*e_r*P_{loss}$.

5. The method of claim 4 wherein, a size of the at least one backup buffer is $\geq m*x \geq x*\frac{\log\left(0.1*s/e_r*x\right)}{\log P_{loss}}$, where m is a number of retransmits that will reduce the loss rate for older packets to a negligibly small number, and $m*x$ is a minimum required size of the at least one player buffer.

6. A method of detecting and reacting to a network congestion which interferes with streaming of multimedia audio and video packets from at least one sending computing device to an at least one receiving computing device via a network, said method comprising the steps of:

a) communicating configuration information including network parameters from a service manager via the network to the at least one sending computing device and to the at least one receiving computing device, the at least one sending computing device comprising at least one server process, the at least one receiving computing device comprising at least one player process;

b) confirming the network congestion by transmitting and retracting network probes;

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c) executing at least one congestion control technique to limit degradation in the streaming of the packets;

d) detecting an end of the network congestion by transmitting and retracting said network probes;

e) configuring a rate of streaming of the packets according to said network parameters

7. The method of claim 6, wherein said at least one congestion control technique is the constant bit-rate emulation.

8. The method of claim 7, wherein said at least one congestion control technique only reduces a transmission rate of the packets by the amount of incurred loss of the packets.

9. The method of claim 7, further comprising the steps of:
detecting an end of congestion;
computing available bandwidth in the network; and
transmitting packets according to said bandwidth.

10. The method of claim 9, wherein some of the at least one player process are differentiated and protected from effects of said network congestion to a greater than others by receiving a stream backlog sooner.

11. The method of claim 10, wherein some of the at least one player process are differentiated and protected from effects of said network congestion to a greater than others by receiving a stream backlog sooner according to a rule for transmission rate of the packets

$$e_t = \min(\alpha^j \times SR_{min}, \alpha^j \times \frac{B - \lambda_{other}}{\sum_{i=1}^{i=K} \alpha^i n^i})$$

, where e_t indicates said transmission rate of packets, α^j is a weighting function, for class $\{1 \ldots K\}$.

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12. The method of claim 11, wherein said detecting of said end of the network congestion is performed according to the expected utilization $\rho = 1 - \frac{SR_{avg}}{B}$, where SR_{avg} is the average rate at which the packets are transferred from the at least one server process to the at least one player process and B is a bottleneck link capacity at a bottleneck hop.

13. The method of claim 12, wherein said network probes compute an approximate service rate of transferring the packets from said at least one server process to said at least one player process according to the following equation:

$SR^{min}_{m,m-1} = \frac{s}{\frac{s}{B_{m,m-1}} + q^{max}_{m,m-1}}$, and $SR^{avg}_{m,m-1} = \frac{s}{\frac{s}{B_{m,m-1}} + q^{avg}_{m,m-1}}$, where SR_{avg} and SR_{min} are averaged and minimum service rate, $q^{max}_{m,m-1}$ is the maximum queuing delay between a node m and a node m-1.

14. A method of guaranteed delivery of streaming multimedia audio and video packets from at least one sending computing device to an at least one receiving computing device via a network, said method comprising the steps of:

a) continuously processing arriving packets;

b) keeping track of loss of the packets at the at least one receiving computing device, said at least one receiving computing device comprising one or more player processes;

c) determining if said loss exceeds a first threshold during a first interval;

d) verifying congestion symptoms;

e) communicating said verified congestion symptoms to the at least one sending computing device, said at least one sending computing device comprising one or more server processes;

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f) monitoring said loss and determining if said loss exceeds a second threshold during a second interval to determine an end of congestion; and

g) verifying congestion symptoms.

15. The method of claim 14, wherein said step of keeping track is performed at user define intervals.

16. The method of claim 15, wherein said first threshold, said second threshold, said first interval, and said second interval are user defined.

17. The method of claim 16, wherein said congestion symptoms are verified by receiving a remote congestion confirmed report.

18. The method of claim 17, wherein said congestion symptoms are verified by performing a congestion probe.

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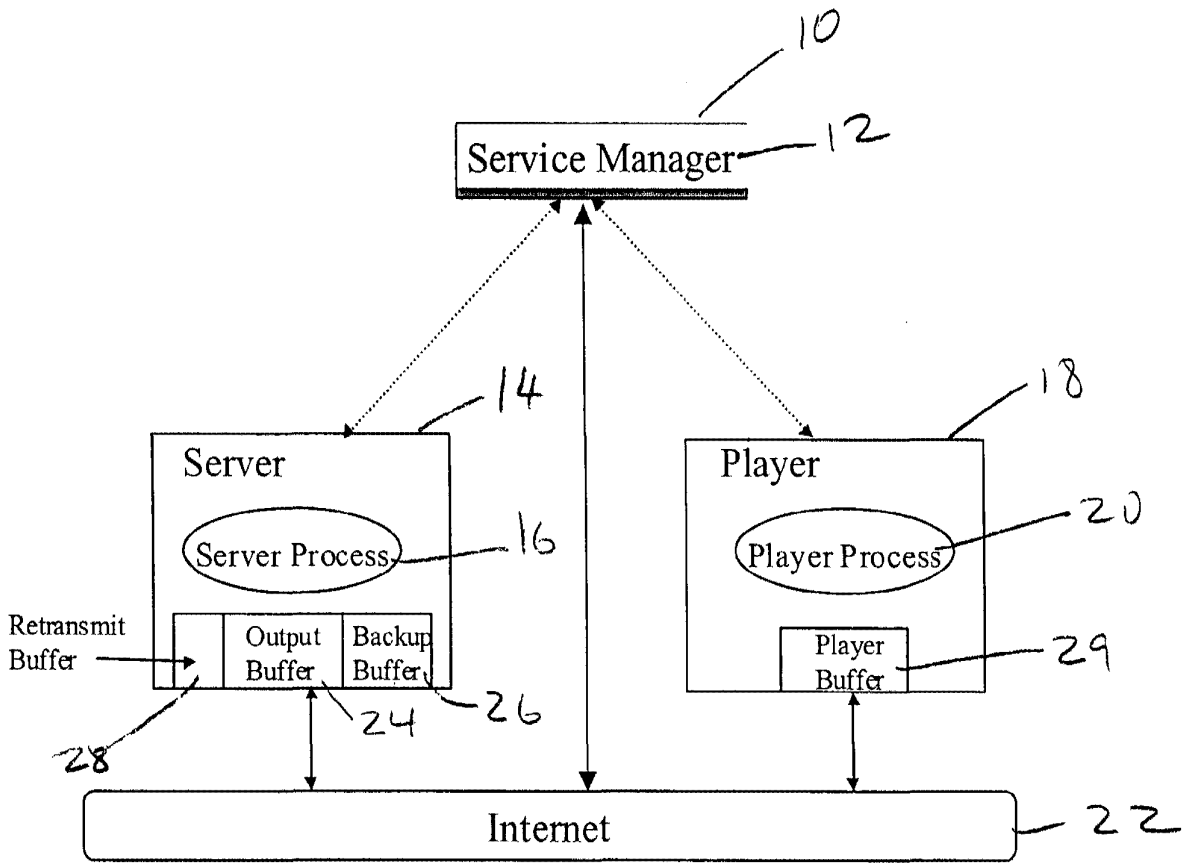


Figure 1

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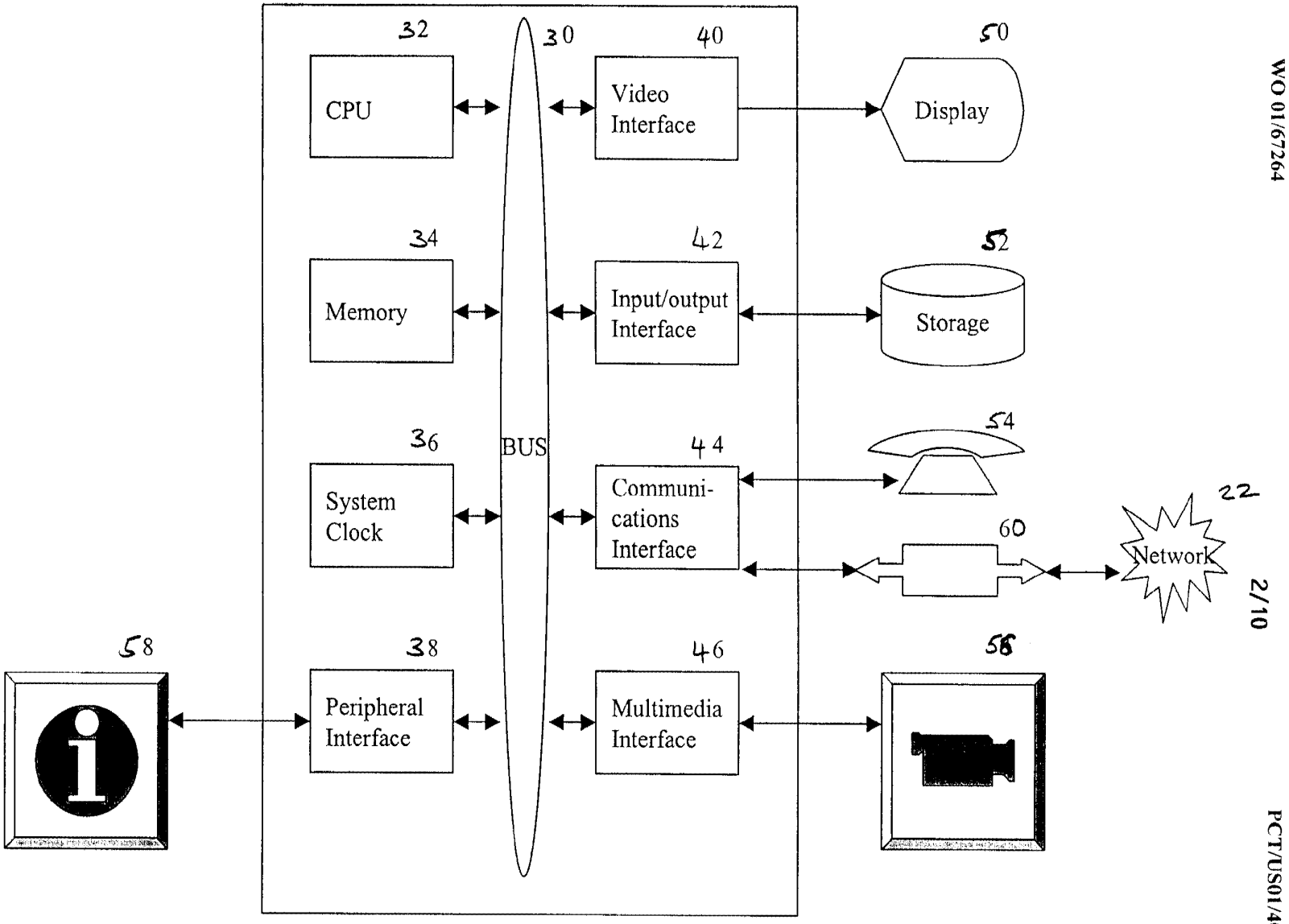


Figure 2

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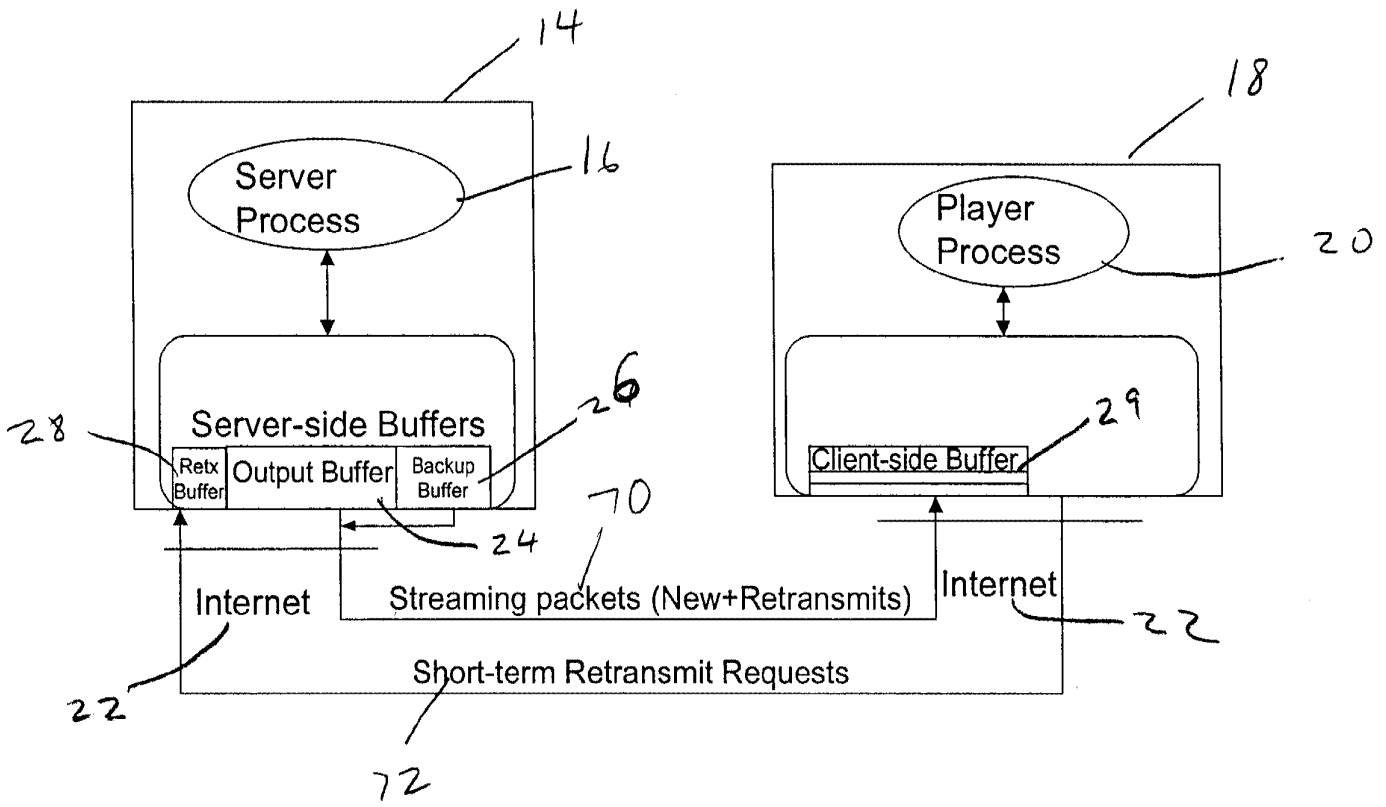


Figure 3

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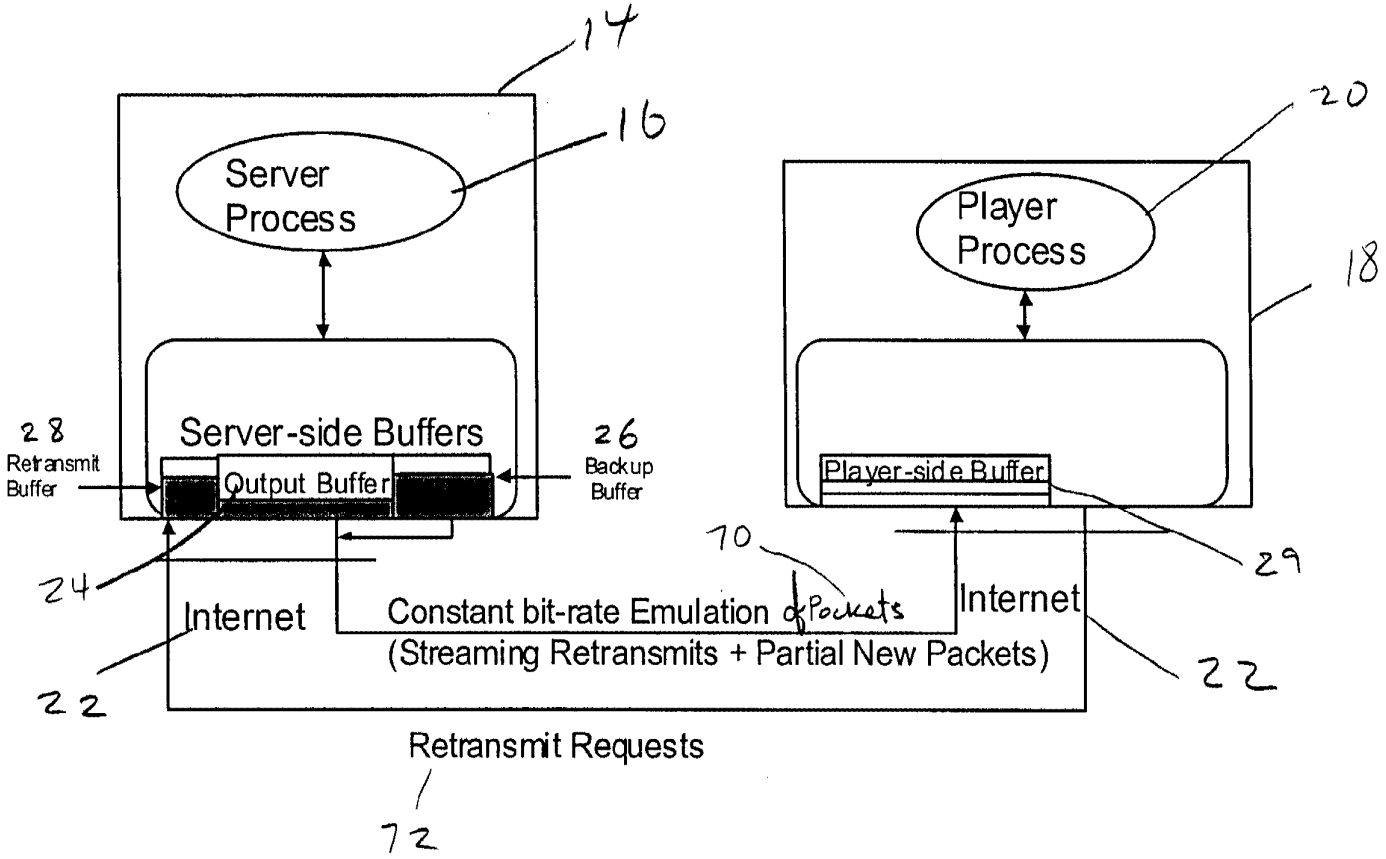

14
16
Server Process
20
Player Process
18
28
Retransmit Buffer
Server-side Buffers
Output Buffer
26
Backup Buffer
Player-side Buffer
29
24
70
Internet
Constant bit-rate Emulation of Packets
(Streaming Retransmits + Partial New Packets)
Internet
22
22
Retransmit Requests
72

Figure 4

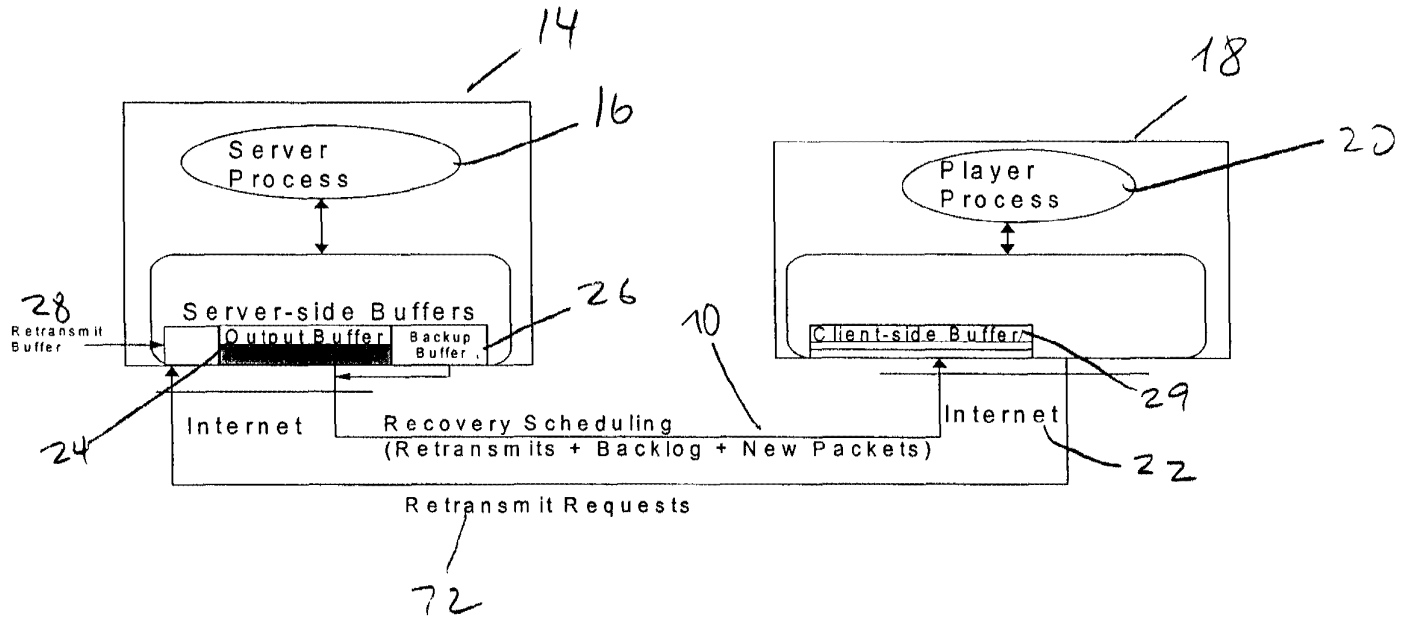


Figure 5

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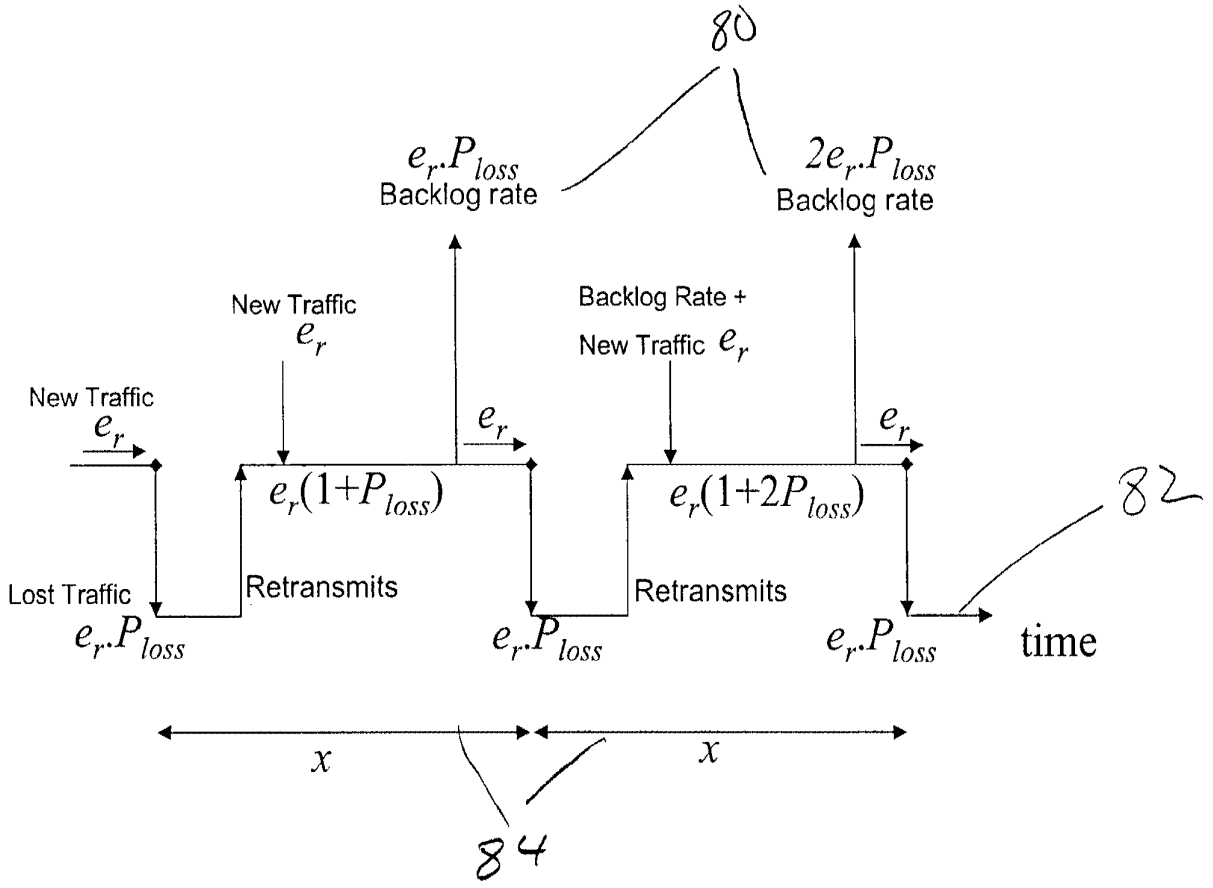


Figure 6

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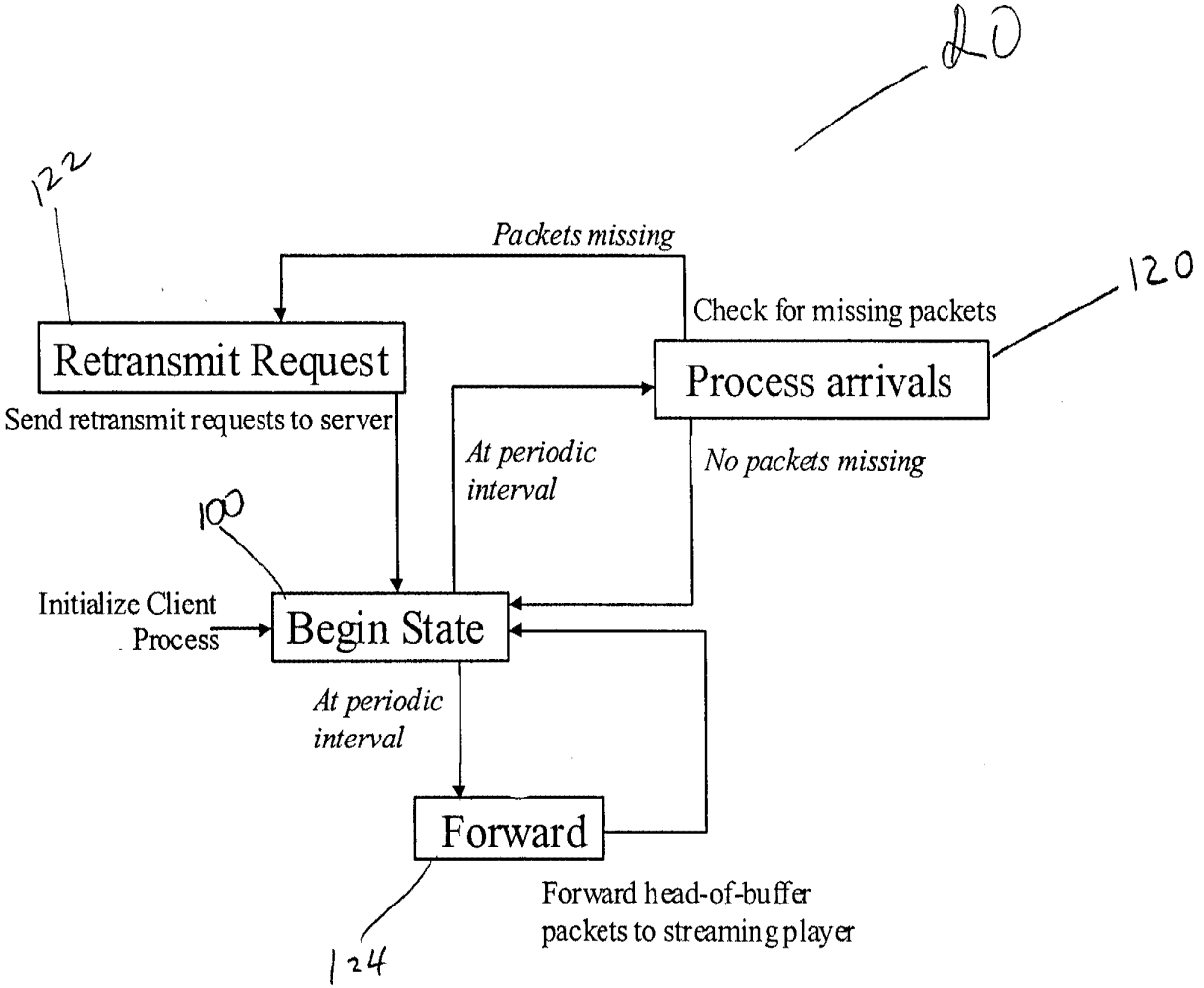


Figure 7

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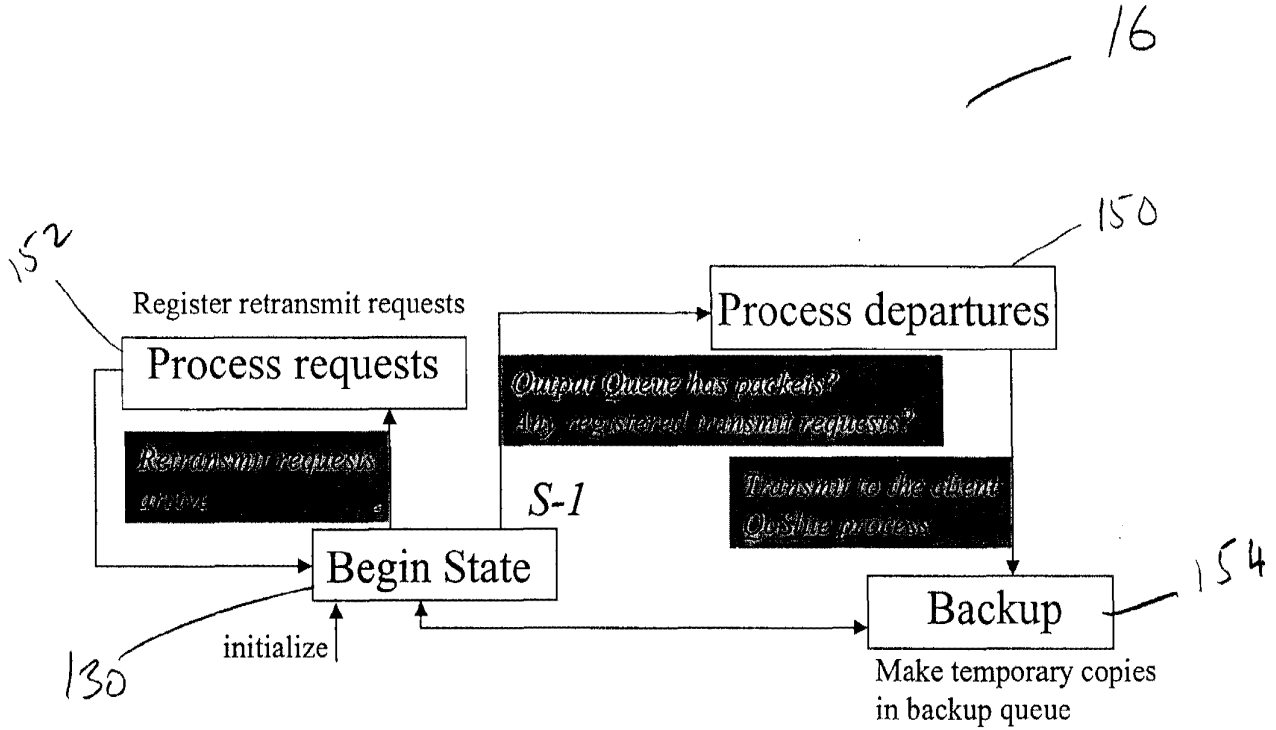


Figure 8

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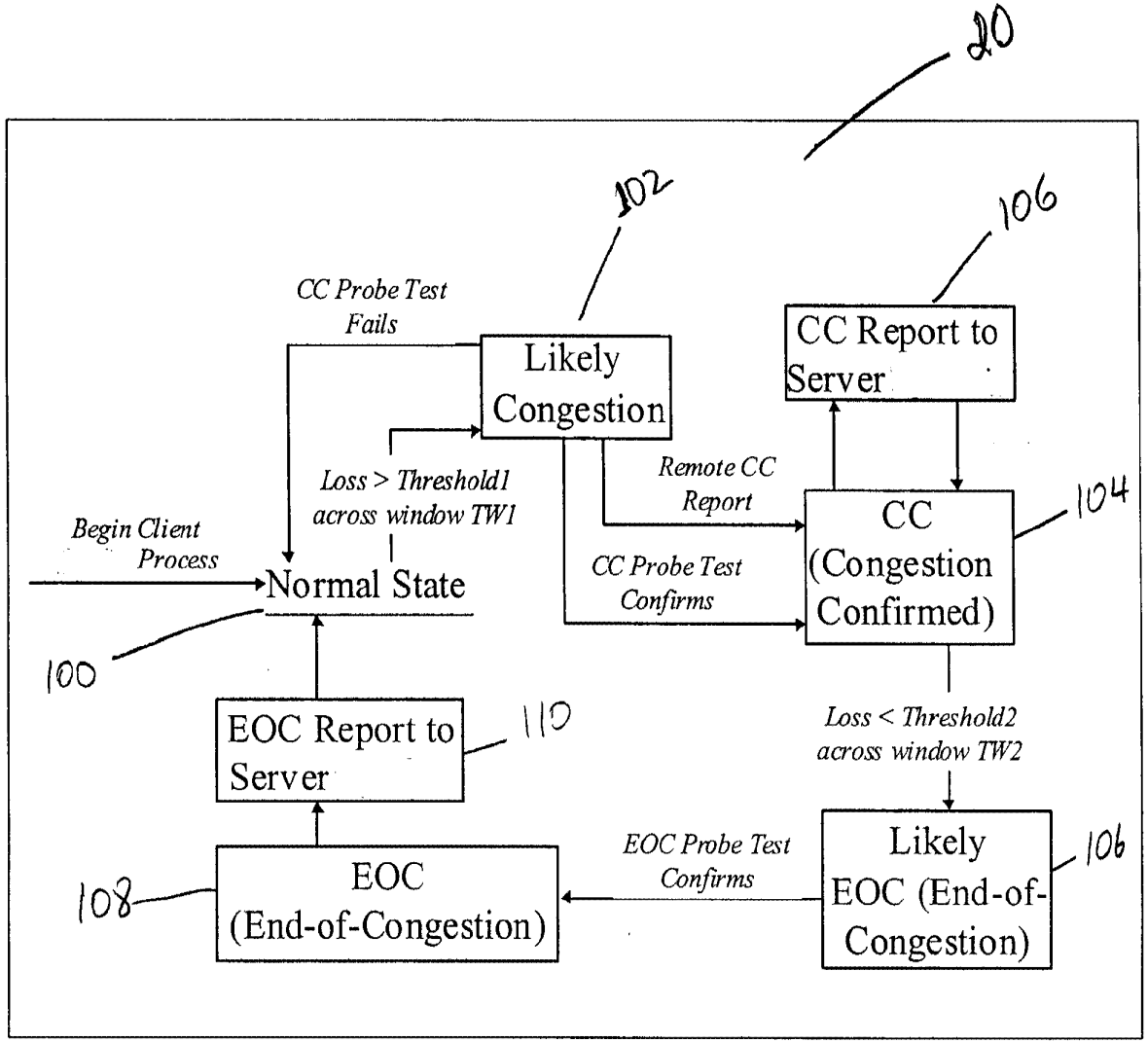


Figure 9

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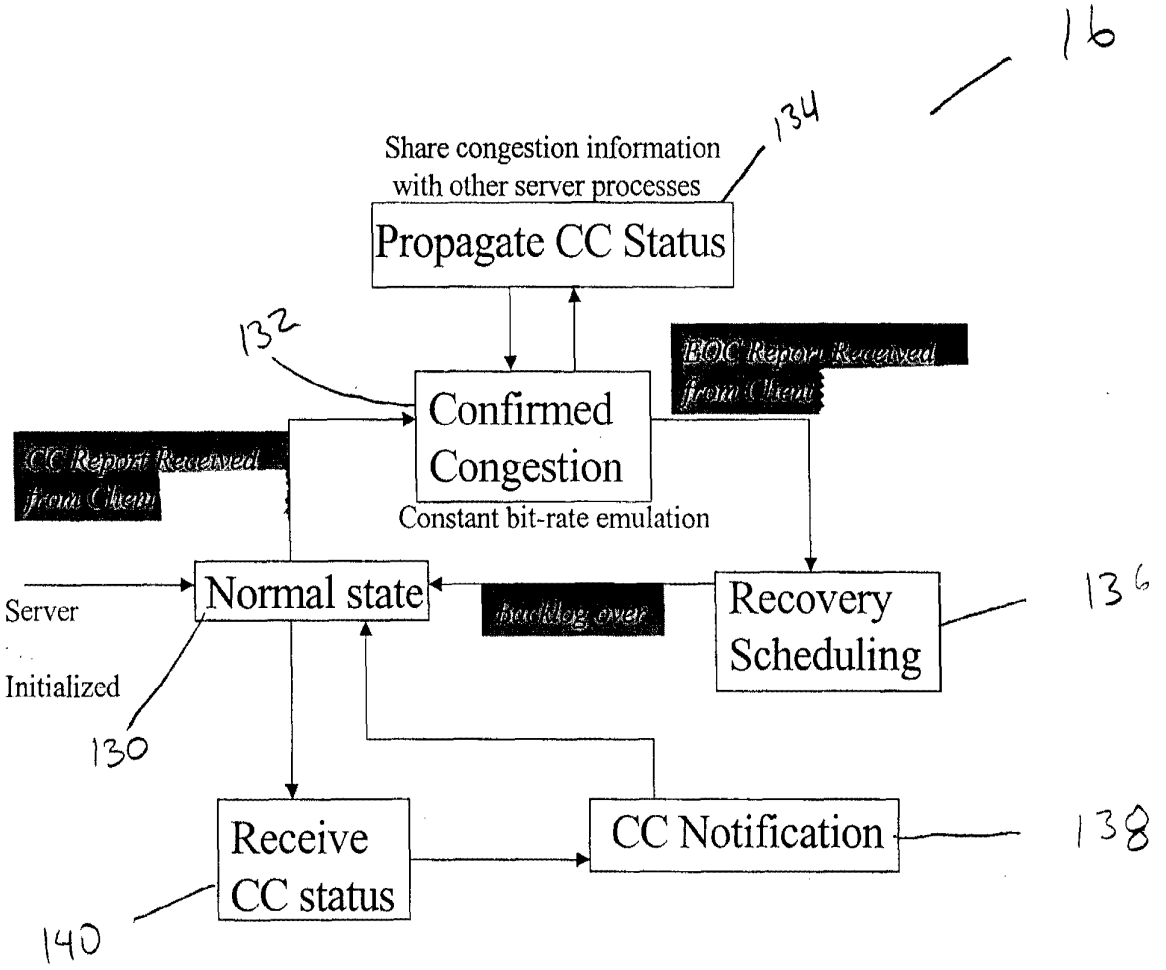

16
Share congestion information
with other server processes
134
Propagate CC Status
132
Confirmed
Congestion
Constant bit-rate emulation
Server
Initialized
130
Normal state
Recovery
Scheduling
136
Receive
CC status
140
CC Notification
138

Figure 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/40264

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) :G06F 15/16
US CL :709/231, 232, 235
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 709/231, 232, 235

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

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

EAST

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X,P	US 6,018,515 A (SORBER) 25 January 2000, col. 4, line 18-col. 10, line 65.	6-10, 14-18
A, P	US 6,014,706 A (CANNON et al) 11 January 2000, see all.	1-18
A	US 5,339,392 A (RISBERG et al) 16 August 1994, see all.	1-18

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

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 06 JUNE 2001	Date of mailing of the international search report 27 July 2001 (27.07.01)
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer Peggy Harwood TOD KUPSTAS Telephone No. 703-305-2655

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	16252188
Filing Date	2019-01-18
First Named Inventor	David F. Brueck
Art Unit	2454
Examiner Name	Patel, Chirag R.
Attorney Docket Number	066.0141X1C7

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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	Attorney Docket Number	066.0141X1C7

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	First Named Inventor	David F. Brueck
	Art Unit	2454
	Examiner Name	Patel, Chirag R.
	Attorney Docket Number	066.0141X1C7

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	Art Unit	2454
	Examiner Name	Patel, Chirag R.
	Attorney Docket Number	066.0141X1C7

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	Application Number	16252188
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The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

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(54) Adaptive video transmission with variable frame rate

(57) Video signals are sent via a network, such as an internet protocol network, the bandwidth of which varies with time. The amount of data to be sent is controlled by varying the frame rate. This is achieved by (a) measuring the transmission capacity to the receiver; (b) determining the rate of change of transmission capacity; and (c) adjusting the transmitted video frame rate as a function of the said rate of change.

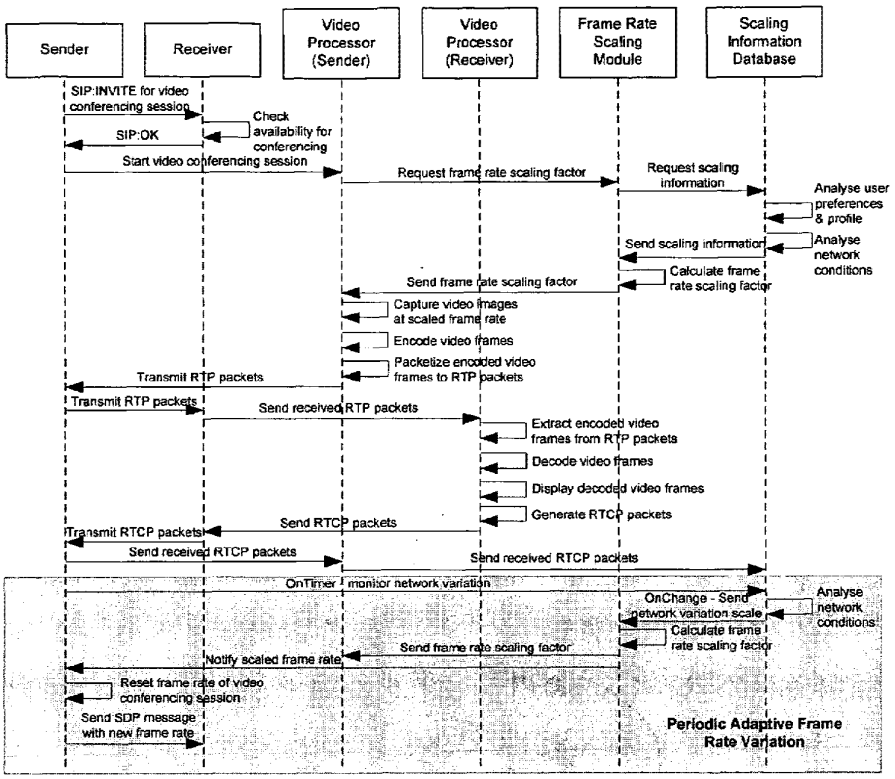


Figure 3 Sequence Diagram of Adaptive Video Frame Rate Application

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Description

[0001] The present invention is concerned with the transmission of video signals via a network.

[0002] In the future, the next generation communication environment is envisaged as allowing users to roam freely and to communicate with each other at any time and any place [1]. Client devices with different capabilities, which range from low power mobile phones to high performance workstations, may be used for communications. Users will be interconnected by networks with various capacities, with packet loss rates that range from almost lossless transmission to quite error prone environments. The rapid development of the client device industry and the proliferation of network access technologies is expected to result in the extensive growth of bandwidth-intensive real-time multimedia internetworking applications (e.g. voice over IP, video streaming, video conferencing and so on).

[0003] Real-time multimedia transmission over a variable bandwidth network environment requires a strict guarantee of network bandwidth and of several other quality of service (QoS) parameters, such as end-to-end delay, delay variation and packet loss. Unfortunately, most of the current QoS mechanisms in existing networks (such as wireless and mobile networks) do not provide such guarantees. In dynamic and unpredictable network environments, due to diverse forms of mobility and interference at the air interface, it gives rise to varying bandwidth and dynamically changing error rates [2]. This further intensifies the challenge for consistent provision of QoS. Traditional QoS mechanisms (e.g. Integrated Services and Differentiated Services), which are typically designed for wired networks, assume a fixed network topology and a fixed amount of available resources. These are inadequate to satisfy users' QoS requirements or to utilize the system resources efficiently, especially in bandwidth-limited and error prone network environments.

[0004] In order to solve this, adaptive multimedia applications are proposed. By implementing adaptive applications, media quality can, in the case of bandwidth variation of network, be adapted appropriately. The bandwidth of the media stream can be scaled down to provide a degraded quality at the destination. In this invention, we are particularly interested in the implementation of video applications. Adaptive video applications use protocols such as Real-Time Streaming Protocol (RTSP) and Real-Time Protocol (RTP), to adapt to changing network conditions using a number of techniques. These techniques include hierarchical encoding, efficient compression, bandwidth smoothing, rate shaping, error control, and adaptive synchronization. Feedback from lower networking layers can be used by the application layer and this helps to match the transmission to the available bandwidth as well as to increase the robustness of the video transmission. However, the perceived quality of video applications is being neglected. Variations of frame rates are proposed in some of these adaptive mechanisms [3] [4]. However, abrupt changes of frame rates can annoy users and hence have a severe impact on the perceived quality of such video applications.

[0005] QoS provisioning is an important issue in real-time internetworking video applications. The dramatic fluctuation of network conditions further intensifies the problems of QoS provisioning. Under variable bandwidth network environments (such as users are moving from one network to another with different bandwidth capacity or network is being congested by heavy traffic), characteristics of video applications need to be adjusted in order to fit the requirements of the current operating network and also maintain the perceived QoS.

[0006] An IBM document on QoS policies [5] clearly states that "the priority for smooth video is higher than the priority for frame quality". It points out that the importance of smooth video is even more significant when users are watching high motion videos (such as sports programmes). Traditional adaptive frame rate variation mechanisms in video applications, which adjust the video requirements according to the rate supportable by the network, attempt to keep the quality of video constant by varying the frame rate. In these mechanisms, the perceived quality of video application is often degraded as frame rates are reduced to a much lower rate or being increased to a much higher rate in order to fit network conditions. The abrupt changes of frame rates (from higher rate to lower rate and vice versa), which cause jerkiness and unsteady video displays, annoy users who are expecting a smooth and continuous flow of video frames in real-time video applications. The users are able to notice the sudden change of frame rate in video transmission. For example, a video application may be sending video at 25 frames per second (fps) during normal network condition and frame rate is reduced to 8fps when network congestion is detected; the frame rate is then increased to 15fps again when network conditions improve. This drastic fluctuation of frame rates will affect the smoothness of the video display and hence have a severe impact on perceived quality.

[0007] References:

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2. M. Naghshineh et al, End-to-End QoS Provisioning in Multimedia Wireless/Mobile Networks Using an Adaptive Framework, IEEE Communication Magazine November 1997.

3. J. Kim et al, TCP-Friendly Internet Video Streaming Employing Variable Frame-Rate Encoding and Interpolation, IEEE Transaction on Circuits and Systems for Video Technology, Vol.10, NO.7, October 2000.

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[4] W. Guetz et al., U.S. Patent 6,091,777.

[5] IBM. Functions of mobile multimedia QoS control. http://www.trl.ibm.com/projects/mmqos/system_e.htm.

[0008] According to the present invention there is provided a method of transmitting video over a network to a receiver, comprising repeatedly

(a) measuring the transmission capacity to the receiver;
(b) determining the rate of change of transmission capacity;
(c) adjusting the transmitted video frame rate as a function of the said rate of change.

[0009] Other aspects of the invention are set out in the claims.

[0010] Some embodiments of the invention will now be described, with reference to the accompanying drawings.

[0011] The basic system operational view of our implementation is depicted in Figure 1. The figure shows one-way communication (sender-to-receiver), however, it can be implemented as a two-way communication application (client-to-client). Session Initiation Protocol (SIP) can be used to start a communication session between two or more clients. Real-Time Protocol (RTP) and

[0012] Real-Time Control Protocol (RTCP) can be used as underlying transport layer to send data packets and also control packets. In this implementation, Session Description Protocol (SDP) signalling can be used to reset the parameters of a video conferencing session and send them to the receiving end.

[0013] The video processor, which involves capture/display, encoder/decoder and transmitter/receiver, is mainly for media processing. The adaptation mechanism appears as a standalone module in the application. A scaling information database extracts and stores network statistical information (monitored periodically using a timer) and user profiles (set by users). The frame rate scaling module is the core mechanism which calculates a frame rate scaling factor based on information obtained from information database. A scaled frame rate will then be fed to the video processor for setting new video parameters.

[0014] Figure 2 illustrates how the different parameters influence the frame rate in the case of fluctuation in the network . To calculate the frame rate scaling factor, several parameters need to be taken into consideration. These parameters may include network statistics, RTCP feedback statistics and the user profile. The main contributor to the scaling factor is the network statistics, where the changes with time (Δbandwidth/Δt) are tracked.

[0015] The sequence diagram (Figure 3) shows the activity flows of our implementation. The periodic adaptive frame rate variation mechanism (shaded portion) is applied to avoid the situation that frame rate variation is only incurred when network congestion is detected. A timer is initiated for periodic network condition monitoring at the client end. The frame rate will be scaled based on the scaling factor extracted from scaling information as discussed previously. This will improve the perceived quality by giving a gradual change of frame rate and smooth playbacks of video throughout entire communication.

[0016] The control mechanism essentially comprises the following steps:

(a) measurement, at intervals, of the network bandwidth $B(t_i)$;
(b) determination of the gradient $\{B(t_i) - B(t_{i-1})\}/(t_i - t_{i-1})$;
(c) determination of a scaling factor *M,* as a function of the gradient *m*;
(d) determination of a new frame rate, multiplying the existing rate by the scaling factor - subject however to the rate remaining within a range determined by preset maximum and minimum values..

[0017] In more detail:

(a) Bandwidth could be measured by any one of a number of conventional methods. If the communication session is peer to peer within a similar subnet, say, in an enterprise scenario, the backhaul link of the connecting equipment could expose its bandwidth availability through its SNMP agent residing in that particular equipment. This could be queried via SNMP calls. On the other hand, in an environment when there are several nodes in the path of its communication, an application level implementation of measuring its delay and thus bottleneck within that particular path could be used. This would suggest bandwidth availability.
Clearly it is important, in terms of reducing the risk of large changes in frame rate, to measure the bandwidth (and adjust the frame rate) at frequent intervals - that is to say, frequent in relation to the rate of change of network conditions. A typical rate might be every 10 seconds. It would be possible to measure the bandwidth once per frame, but this is not preferred, in that it involves additional overheads. In theory the bandwidth could be measured more often than once per frame, but naturally the frame rate adjustment cannot occur more often than once per frame.
(b) The gradient is determined by the formula given above. The use of the gradient rather than simply the absolute value of the bandwidth is significant because it introduces an element of prediction into the assessment of bandwidth availability.
(c) The determination of the scaling factor *M* as a function of the gradient *m* should be such that

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If *m* is large & positive, multiplier is >1;
If *m* is small & positive, multiplier is > 1 (but smaller than when *m* is large);
If *m* is 0, multiplier is 1;
If *m* is small & negative, multiplier is <1;
If m is large & negative, multiplier is <1 (but smaller than when *m* is small and negative.
For example, a possible relationship for the situation where the bandwidth gradient is expected to vary over the range -50 to 50 kbit/s/s is: that M varies between 0.4 and 2.5. A simple, piecewise-linear implementation would be to specify that for m>0: M = 1 + 0.03 m; for m=0: M = 1; and for m<0: M = 1 + 0.012 m. However we prefer a nonlinear relationship in which frame rate changes are more extreme at the ends of the scale. Such a relationship would best be implemented by the use of a look-up table.
(d) A typical limit range for frame rate might be from 10 to 25 frames per second. Thus if the existing frame rate is f_i then the new frame rate will be

$$f_{i+1} = \mathrm{Max}\{\mathrm{Min}\{Mf_i, 25\}, 10\}.$$

[0018] The user preferences referred to earlier could mean constraints on the level of adaptation that the user is prepared to live with in a congested network situation, i.e reaction time, image resolution resizing, colour depth. This could influence the extent for the need to switch to a lower frame rate.

[0019] In order to achieve better perceived quality of real-time internetworking video application in variable bandwidth network environments, degradation of video quality needs to be occur gracefully. In the method we have described, an adaptive mechanism, which resides in the video application, allows smooth variation of frame rates under variable bandwidth network environments. It varies frame rates gradually and hence minimises the jerkiness and flickering of video displays. A gradual degradation or upgrade of video quality gives an illusion to users that there is only little change in video quality throughout the communication period. The variation incurred is less aggressive and significant as compared with traditional frame rate variation mechanisms.

[0020] The method improves the perceived QoS of real-time internetworking video applications by implementing smooth variation frame rate mechanism of adaptive video application. An adaptation mechanism resides in a real-time internetworking multimedia application to adapt video quality dynamically to changes in network conditions. Network conditions are absorbed and analysed from time to time and network statistical analysis is then fed back to the video processor of the application. The application is then triggered to set the frame rate of the video to a requested rate based on the analysis of network conditions. The frame rate changes dynamically when network conditions vary - but not only when network congestion is detected. The degree of variation in frame rate depends on the degree of variation in network conditions (such as network utilization) and the variations of frame rates occur throughout the communication session. Hence, it prevents sudden changes in frame rate of the video transmission and helps to minimise the jerkiness of video displays under variable bandwidth conditions. User preferences and profiles may also be taken into account when frame rate is being adjusted. This further improves user perceived QoS of the application.

Claims

1. A method oftransmitting video over a network to a receiver, comprising repeatedly

   (a) measuring the transmission capacity to the receiver;
   (b) determining the rate of change of transmission capacity;
   (c) adjusting the transmitted video frame rate as a function of the said rate of change.

2. A method according to claim 1 in which the frame rate is adjusted to equal the existing frame rate multiplied by a factor which is a monotonically increasing function of rate of change of transmission capacity.

3. A method according to claim 2 in which the factor is a nonlinear function of rate of change of transmission capacity.

4. A method according to claim 3 in which the factor is obtained by means of a look-up table.

5. A method according to any one of the preceding claims in which the rate of change of transmission capacity is evaluated to determine whether an adjustment of frame rate is necessary at regular intervals.

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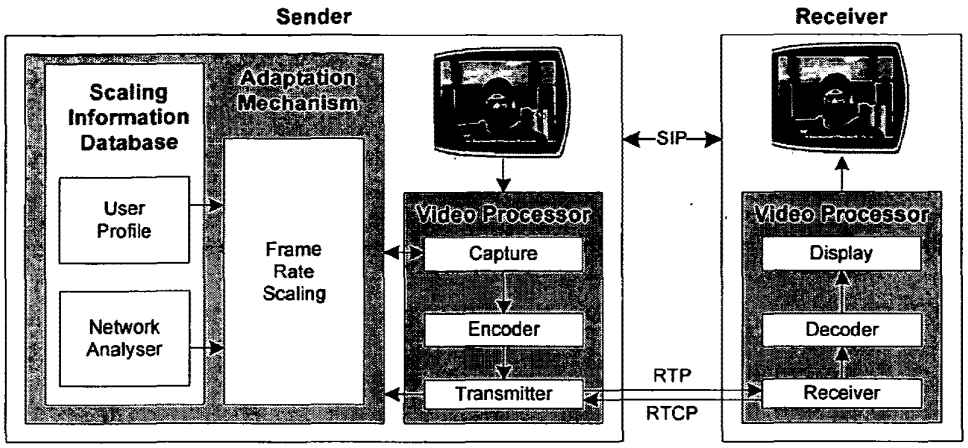


Figure 1 Basic System Operational View

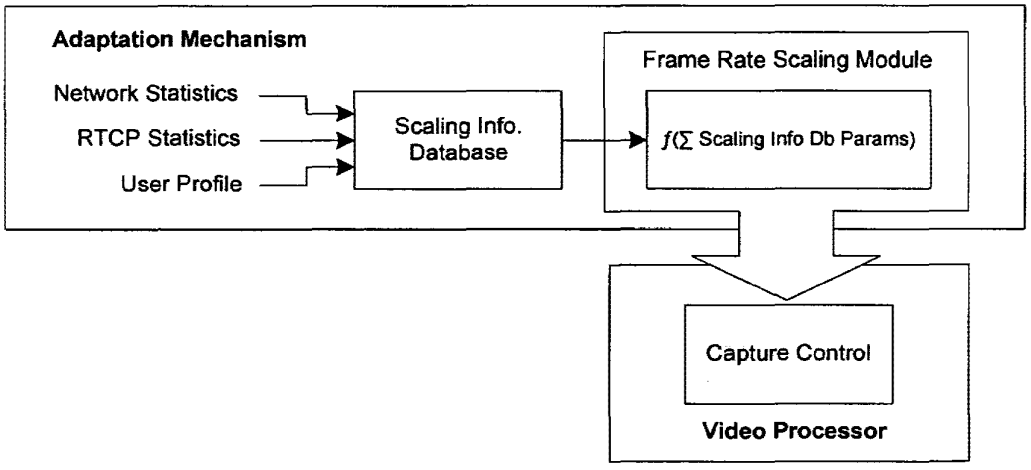


Figure 2

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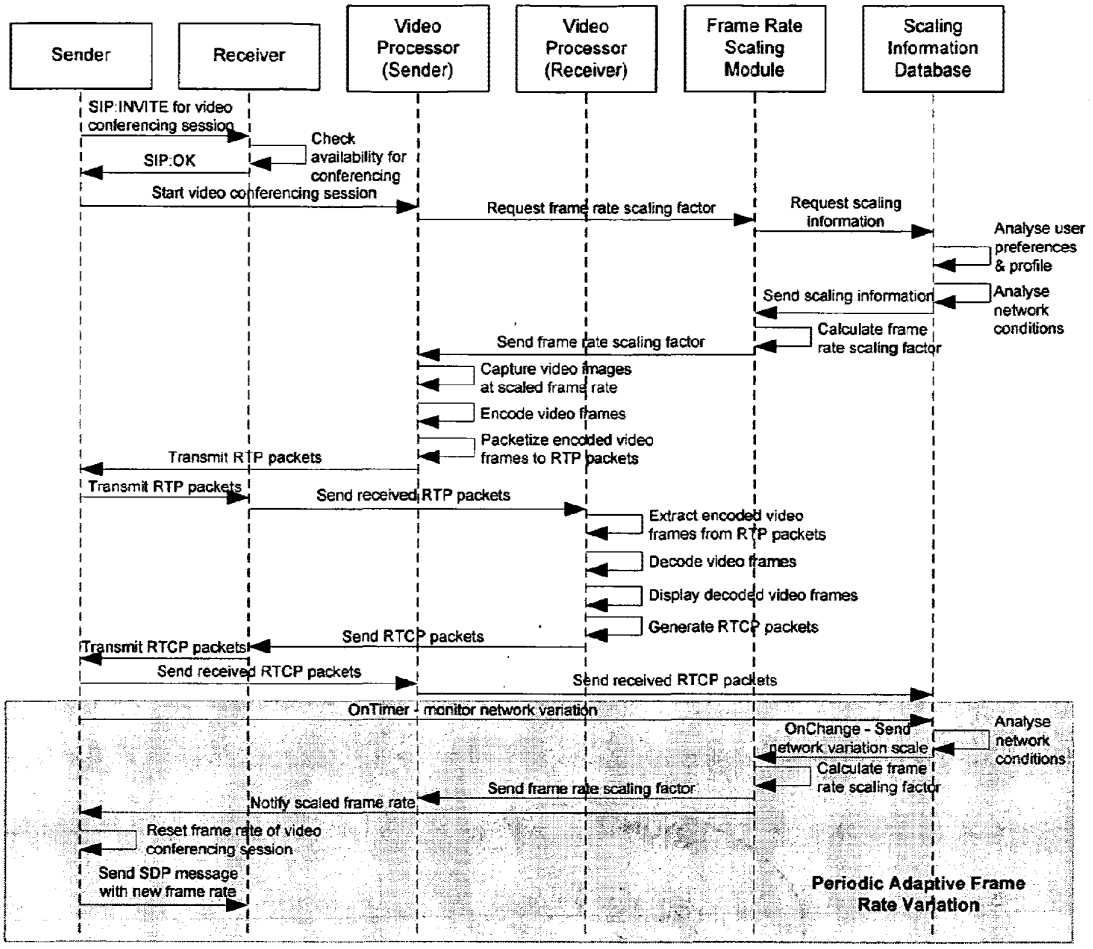


Figure 3 Sequence Diagram of Adaptive Video Frame Rate Application

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Application Number
EP 05 25 6302

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X,D	KIM JONGWON ET AL: "TCP-Friendly Internet Video Streaming Employing Variable Frame-Rate Encoding and Interpolation" IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS FOR VIDEO TECHNOLOGY, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 10, no. 7, 1 October 2000 (2000-10-01), pages 1164-1177, XP002369021 ISSN: 1051-8215 * page 1168, left-hand column, paragraph B *	1-5	H04N7/46
A	REED E C ET AL: "CONSTRAINED BIT-RATE CONTROL FOR VERY LOW BIT-RATE STREAMING-VIDEO APPLICATIONS" IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS FOR VIDEO TECHNOLOGY, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 11, no. 7, July 2001 (2001-07), pages 882-889, XP001083363 ISSN: 1051-8215 * page 885, right-hand column - page 886, left-hand column *	1-5	TECHNICAL FIELDS SEARCHED (IPC) H04N
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Berlin	28 March 2006	Raeymaekers, P

CATEGORY OF CITED DOCUMENTS

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Application Number
EP 05 25 6302

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	NEE P ET AL: "The performance of two-dimensional media scaling for Internet videoconferencing" NETWORK AND OPERATING SYSTEM SUPPORT FOR DIGITAL AUDIO AND VIDEO, 1997., PROCEEDINGS OF THE IEEE 7TH INTERNATIONAL WORKSHOP ON ST. LOUIS, MO, USA 19-21 MAY 1997, NEW YORK, NY, USA,IEEE, US, 19 May 1997 (1997-05-19), pages 223-234, XP010251701 ISBN: 0-7803-3799-9 * page 226, right-hand column * -----	1-5	

TECHNICAL FIELDS SEARCHED (IPC)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Berlin	28 March 2006	Raeymaekers, P

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Electronic Acknowledgement Receipt

EFS ID:	36433084
Application Number:	16252188
International Application Number:	
Confirmation Number:	3722
Title of Invention:	APPARATUS, SYSTEM, AND METHOD FOR MULTI-BITRATE CONTENT STREAMING
First Named Inventor/Applicant Name:	DAVID F. BRUECK
Customer Number:	70560
Filer:	Brett Carlson/Julie Graf
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Attorney Docket Number:	066.0141X1C7
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Application Type:	Utility under 35 USC 111(a)

Payment information:

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Payment Type	CARD
Payment was successfully received in RAM	$240
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(43) Date of A Publication 27.03.2002

(21) Application No 0023062.3

(22) Date of Filing 20.09.2000

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H03M 7/30 , H04L 1/00

(52) UK CL (Edition T)
H4P PDCFM

(56) Documents Cited
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WO 98/09387 A1
US 5847760 A
WO 99/00984 A1
WO 00/72601 A2

(58) Field of Search
UK CL (Edition S) **H4P PDCFM PDCFP PDCFX PF**
INT CL[7] **H03M 7/30 , H04L 1/00 , H04N 7/26 7/32**
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(54) Abstract Title
Streaming of media file data over a dynamically variable bandwidth channel

(57) A method of transmitting data streams over a variable bandwidth channel, comprising modifying the quantity of data to be injected into the channel to accord with a measured capacity or bandwidth of the channel. An input stream is passed through a plurality of parallel compressors 40.1-40.4 which each produce an output stream of a different rate to the other streams. Each stream preferably comprises key or reference frames and delta frames. The reference frames are synchronized between the streams so that a data unit in one stream contains the same information as the corresponding data unit in another stream, but is compressed to a different extent. A data stream for transmission along the channel is produced by selecting data units from more than one compressor output stream so as to produce a stream which makes optimum use of the available channel bandwidth. In one embodiment the duration of the data units are one of a group comprising fixed predetermined durations and duration determined by changes in the channel bandwidth. The method is useful in sending multimedia data streams such as audio and video over a channel such as a cellular telephone network or the internet.

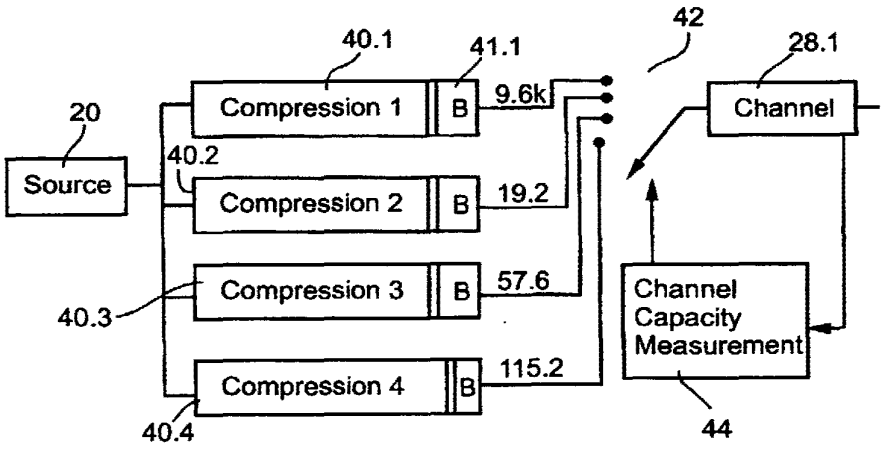


Fig. 4

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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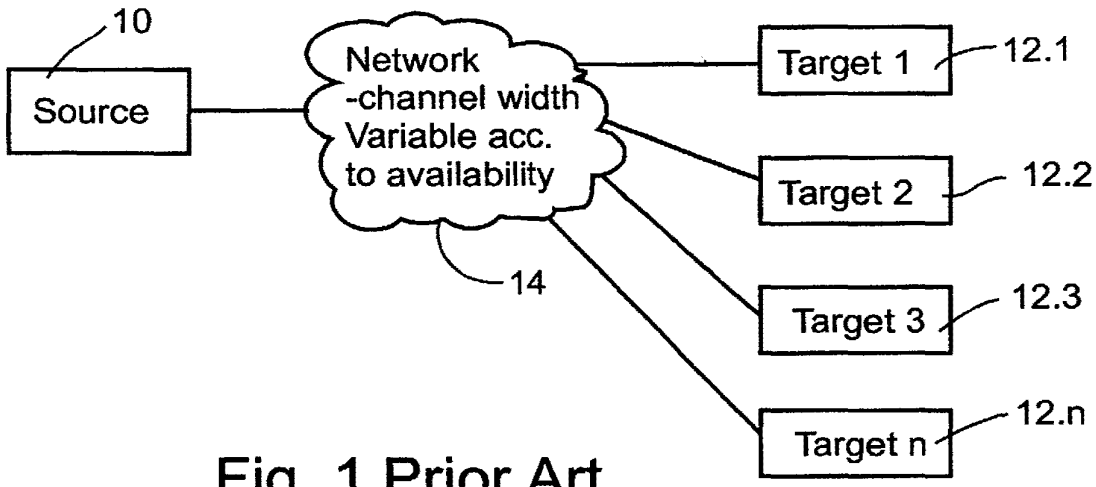


Fig. 1 Prior Art

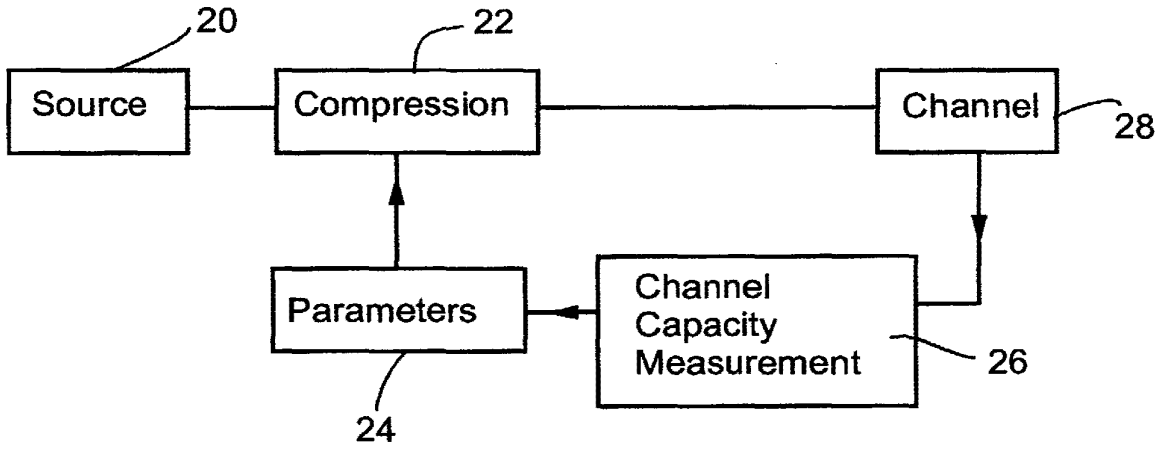


Fig. 2

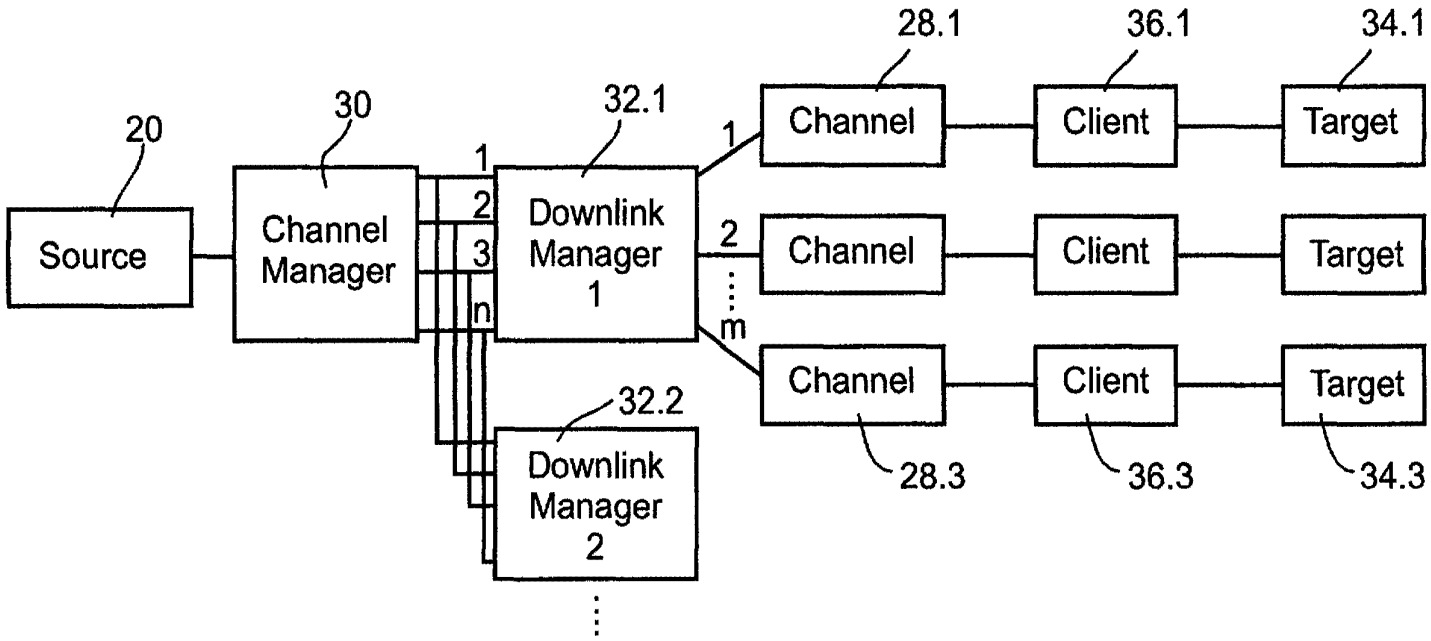


Fig. 3

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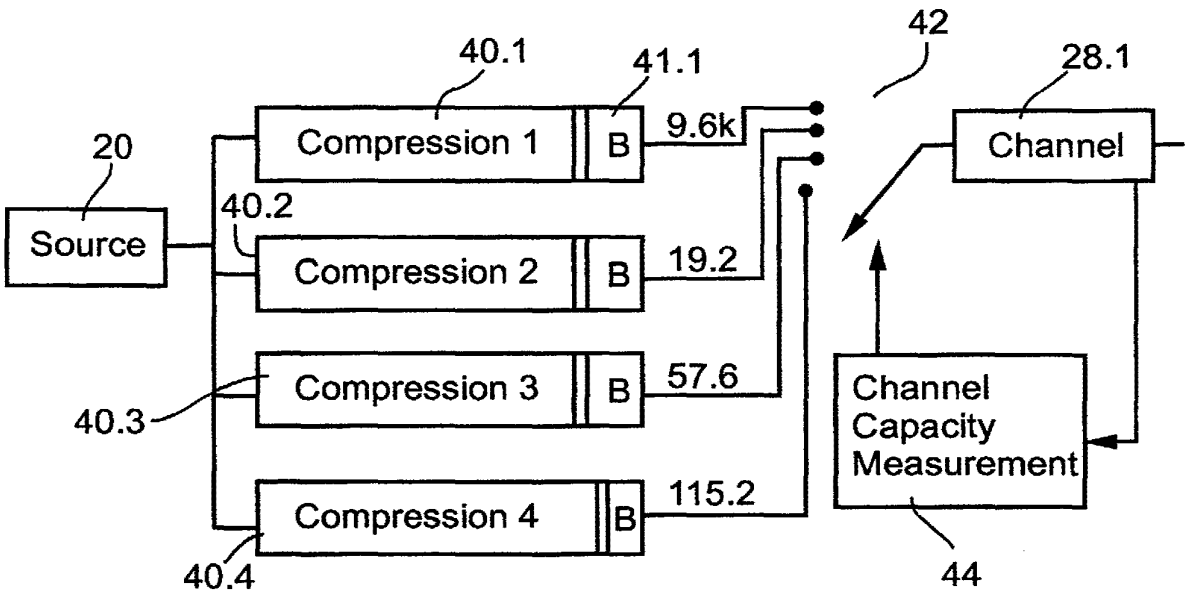

40.1
41.1
42
28.1
20
Compression 1
B
9.6k
Channel
40.2
Source
Compression 2
B
19.2
Compression 3
B
57.6
40.3
Channel
Capacity
Measurement
Compression 4
B
115.2
40.4
44

Fig. 4

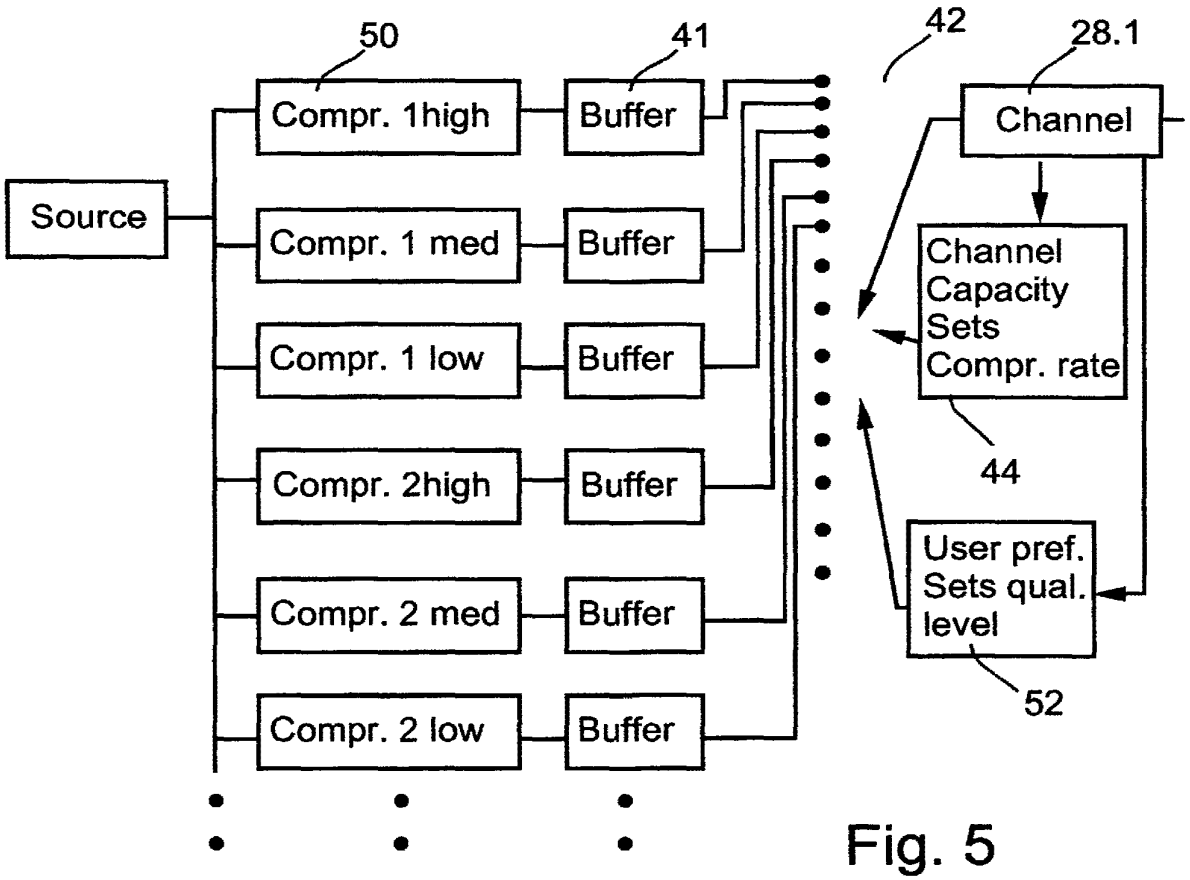

50
41
42
28.1
Compr. 1high
Buffer
Channel
Source
Compr. 1 med
Buffer
Channel
Capacity
Sets
Compr. rate
Compr. 1 low
Buffer
44
Compr. 2high
Buffer
User pref.
Sets qual.
level
Compr. 2 med
Buffer
52
Compr. 2 low
Buffer

Fig. 5

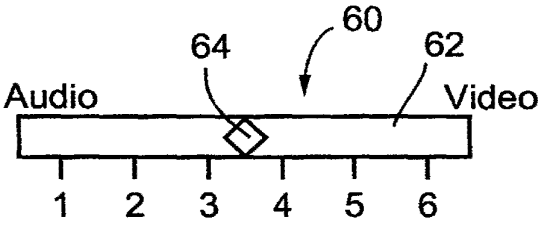


Fig. 6

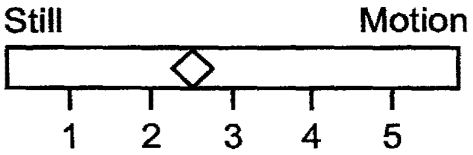


Fig. 7

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Title of the Invention

Streaming of Media File Data Over a Dynamically Variable Bandwidth Channel

Field of the Invention

The present invention relates to streaming of media file data over a channel having a dynamically variable bandwidth, and more particularly but not exclusively to streaming of multimedia data such as video and /or audio data over a channel having a dynamically variable bandwidth.

Background of the Invention

Dynamically varying channel bandwidths are particularly encountered over the Internet and like networks and over radio and cellular telephone links. On the Internet the total bandwidth is fixed and the bandwidth available per channel tends to depend on the amount of usage, the greater the usage the smaller the bandwidth available per user. In radio and cellular links the available bandwidth depends on usage, but the overall capacity may also be dependent on environmental factors.

The Internet relies on packet switched communication, whereas radio and cellular telephone links may be either circuit-switched or packet switched. Either way, the same considerations of channel bandwidth broadly apply.

As the bandwidth changes, a number of approaches are currently in use. One of these is simply to buffer received video frames, to start to show the frames as soon as the buffer is full, and to continue to show the video until the buffer is empty, then to halt the display until the buffer is full again. Another method is to show the video at a real time rate, displaying all frames that arrive in time and dropping all frames that arrive too late.

In both of these methods, data is sent at the same high rate. In the first method, unacceptable delays in showing the data are experienced. In the second method, valuable channel bandwidth is wasted transmitting data that does not get used.

Whether the network is a cellular telephone network or the Internet or like wide area data network, the bandwidth of the data network is variable. In all cases the

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larger the number of users the lower the bandwidth per user, and radio-based networks may also suffer from reduced bandwidth due to environmental conditions. Furthermore, in the case of cellular telephone networks, events such as handover between two base stations may also affect the available bandwidth.

In general, cellular networks are able to absorb changes in bandwidth without the user noticing a change in the quality of the voice signal. However, it is desirable to go beyond mere voice communication over cellular telephone networks. Already, low level data capability is being built into mobile telephones and it is envisaged that within the next few years, mobile telephones will be able to receive and display multimedia data. Multimedia data uses large amounts of bandwidth and generally requires to be displayed in real time. Thus bandwidth fluctuations will be immediately noticeable. Currently, however, transmission of video data over cellular phone channels is not being attempted on a commercial basis.

At present, mobile telephone systems are on their second generation and a third generation is on the drawing board but will not be available for some years. The problem is particularly associated with the design of advanced second generation equipment (generation 2.5) which, it is envisaged will be able to provide multimedia within the limitations of second generation capacity. It should be noted however that the same considerations apply to further generations of mobile telephones and also to other environments in which it is desired to transmit multimedia data, such as the Internet.

Generally, multimedia data is sent over a network as a datastream in compressed form. There are numerous algorithms for compressing data, and different forms of compression are appropriate for compressing different forms of data. Furthermore, a single form of compression may give rise to different levels of compression according to compression parameters that may be set. The greater the compression the lower will be the resulting data rate and a high level of compression may be used to overcome channel capacity constraints. A solution may involve selection of the compression parameters to meet a likely worst-case scenario. However, the solution is not complete as a high level of compression leads to low quality output and no advantage is taken of the availability for most of the transmission time of a higher bandwidth availability.

US Patent No. 6,014,694, Aharoni et al, discloses a system for adaptively transporting video over networks wherein the bandwidth varies with time. The

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system comprises a video/audio codec that functions to compress, encode, decode and decompress video streams that are transmitted over networks having available bandwidths that vary with time and location. Depending on the channel bandwidth, the system adjusts the compression ration to accommodate a plurality of bandwidths ranging from 20kbps for POTS to several Mbps for switched LAN and ATM environments. Bandwidth adjustability is provided by offering a trade-off between video resolution, frame rate and individual frame quality. The system generates a video data stream comprising of key, P and B frames from a raw video source. Each frame type is further comprised of multiple levels of data representing varying degrees of quality. In addition, several video server platforms can be utilized in tandem to transmit video/audio information with each video server platform transmitting information for a single compression/resolution level.

P and B frames are delta frames that depend on previous frames to allow a complete picture to be generated. Thus it is not possible simply to mix groups of frames of different quality levels since the deltas between frames are different. The above US Patent solves the problem by taking advantage of what is known as a group of pictures (GOP) which is a self-contained unit such as a scene. Because they are self-contained, GOPs of different compression levels can be successfully mixed. However, GOP boundaries are content related and thus irregular. When GOP boundaries are widely spaced, dynamic following of bandwidth changes are highly inaccurate or generate delays for new users.

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Summary of the Invention

Embodiments of the present invention attempt to solve the above problems by modifying the quantity of data to be injected into the channel to accord with a measured capacity or bandwidth of the channel. The quantity of data is preferably modified only by altering compression parameters, so that data fully usable in real time can be received from the channel. Thus a reduction in bandwidth of the channel leads to a drop in quality of the received signal and not to dropped frames or a reduction in performance.

According to a first aspect of the present invention there is thus a device for streaming of media file data to be sent over at least one channel having a dynamically variable bandwidth, comprising

an input for receiving media file data at a first rate,

a multiple stream creator for creating a plurality of streams of said media file data, each stream compressed to predetermined other rates, each stream comprising a series of autonomous compressed data units which are mutually compatible, and

a stream selector for dynamically matching a bandwidth of the channel to rates of said streams to send said data file as a combination of said autonomous units from said streams via said channel,

wherein said autonomous units have durations which are one of a group comprising fixed predetermined durations and durations determined by changes in said channel bandwidth.

Preferably, said stream selector is operable to select a combination of said streams in succession said combination being chosen to produce an average stream rate over a period of time which matches said channel bandwidth.

Preferably, said bandwidth of said channel is liable to vary dynamically and wherein said stream selector is operable to repeat said matching throughout said streaming operation.

Preferably, said bandwidth of said channel is liable to vary dynamically and wherein said stream selector is operable to repeat said matching throughout said streaming operation.

Preferably, said autonomous units match each other across said plurality of streams, thereby to enable switching between said streams.

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Preferably, said data file is arranged in said streams in a compressed media format utilizing reference frames and delta frames and wherein each autonomous unit is self-contained in respect of reference frames.

In an embodiment, said channel is a cellular telephone channel. Alternatively, said channel is an Internet channel.

Preferably, the predetermined other rate is different for each stream. In another embodiment, the predetermined other rate is identical for a set of said streams, each stream in said set being assigned a different balance between quality and speed of said media.

A preferred device comprises a plurality of media types, said predetermined other rate being identical for a set of said streams, each stream in said set being assigned a different balance between quality of said different media types.

Preferably, streams in said set are selectable by a signal received from said channel.

Preferably, streams in said set are selectable by a signal received from said channel.

An embodiment comprises a detector for detecting a change in the bandwidth of said at least one channel and operable to request a corresponding change in the data rate, and wherein the device is operable, upon receipt of said request, to set a delay, and to issue a reference frame within said delay.

The device preferably issues said reference frame at the end of said delay.

The device alternatively issues said reference frame at the occurrence of a largest detected interframe change within the time delay.

According to a second aspect of the invention there is provided a multiple stream creator for receiving a data stream at a first data rate and converting said data stream into a plurality of data streams at a plurality of data rates, said creator comprising an input for receiving said data stream at said first data rate, and a plurality of outputs, each operable to receive said data stream at said first rate and to output said data stream at a predetermined rate individually set for each output as a series of autonomous units having a duration, and wherein said duration is one of a group comprising a fixed predetermined duration and a duration dynamically changeable in accordance with bandwidth conditions in a transmission channel.

Preferably said outputs each comprise data buffers.

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The multiple stream creator preferably comprises a data stream processor for processing said data stream received at said first rate into said plurality of autonomous units, said autonomous units being synchronized blocks, thereby allowing said output streams to be mixed in said transmission channel to produce continuously usable output.

Preferably, said received data stream is in an uncompressed data format and said data is compressed into a compressed data format independently for each one of said output data streams.

According to a third aspect of the invention there is provided a method of sending a datastream over a variable bandwidth channel comprising modifying a quantity of data to be injected into the channel to accord with a measured capacity of the channel, said method comprising the steps of

compressing the datastream, using an algorithm having compression parameters, to produce a plurality of compressed datastreams each comprising reference frames and delta frames, each compressed datastream produced by using the algorithm together with different parameters, and

synchronizing reference frames between the compressed datastreams so that combinations of said compressed datastreams can be sent via said channel.

Preferably, said step of synchronizing reference frames is carried out at intervals determined by a dynamic status of said channel bandwidth.

Alternatively or additionally, said step of synchronizing reference frames is carried out at predetermined intervals.

Alternatively or additionally, said combination of said compressed datastreams is selected substantially dynamically to match the measured capacity of the channel.

Preferably, a change in bandwidth of a channel causes a request for commencement of a new autonomous unit, and wherein said request causes initiation of measurement of a time delay, and wherein a new autonomous unit is commenced within said time delay.

Preferably, the new autonomous unit is commenced at the end of said time delay.

Preferably, the step is provided of determining the largest delta frame during the time delay and sending a reference frame, to initiate said new autonomous unit, in place of said determined largest delta frame.

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According to a fourth aspect of the present invention there is provided a tool for controlling receipt of media file data over a network, wherein said media file data is available at a plurality of quality levels, the tool comprising a quality selector to enable a user to select between said different quality levels for receipt.

Preferably, said media file comprises a plurality of data groups and each quality level is a different balance between quality levels of the plurality of data groups.

Preferably, said quality selector comprises a slider operable to be moved along a scale, the position of the slider on the scale indicating a quality level.

Brief Description of the Drawings

For a better understanding of the invention and to show how the same may be carried into effect, reference will now be made, purely by way of example, to the accompanying drawings, in which:

Fig. 1 is a generalized diagram showing a data source sending data to a series of targets over a variable bandwidth network,

Fig. 2 is a generalized block diagram showing a first embodiment of the present invention in which feedback concerning available bandwidth within a channel is used to modify parameters governing compression of the datastream,

Fig. 3 is a generalized block diagram showing a second embodiment of the present invention in which a series of compressed datastreams are continually created and are selected for use in individual channels according to measured parameters of the channel,

Fig. 4 is a generalized block diagram showing the channel manager and part of a downlink manager of Fig. 3 in greater detail,

Fig. 5 is a generalized block diagram showing a third embodiment of the present invention in which the user is able to set a quality level of the data that is being sent,

Fig. 6 is a generalized schematic diagram of a quality level selection tool for use by a user in selecting a quality level in the embodiment of Fig. 5, and

Fig. 7 is a generalized schematic diagram of another quality level selection tool for use with the device of Fig. 5.

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Description of the Preferred Embodiments

Reference is now made to Fig. 1, which is a generalized diagram showing a data source 10 sending data to a series of targets 12.1..12.n over a variable bandwidth network 14. The network may be a cellular telephone network or the Internet or like wide area data network or a combination. In both cases, the bandwidth of the data network is variable. In all cases the larger the number of users the lower the bandwidth per user, and radio-based networks may also suffer from reduced bandwidth due to environmental conditions. Furthermore, in the case of cellular telephone networks, events such as handover between two base stations may also affect the available bandwidth.

Data is generally compressed before sending over the channel. The level of compression may be preselected to accord with known or likely channel capabilities, as described in the introduction. However such a solution has to concentrate on the lower margins of available bandwidth and thus fails to make full use of higher bandwidth levels when available. Conversely, solutions which send datastreams at higher data rates and do not take the lower bandwidth levels into account lead to unacceptable breaks and delays in performance at the receiving end.

Reference is now made to Fig. 2 which is a generalized block diagram showing a first embodiment of the present invention in which feedback concerning available bandwidth within a channel is used to modify parameters governing compression of a datastream.

A multimedia datastream is received from a source 20 such as a host or server. The datastream may be a video datastream and may be in uncompressed or barely compressed format, for example AVI or MPEG1. The datastream is passed to a compression unit 22 which compresses the data into a very low bit-rate stream using compression parameters. A typical format that may be used for the very low bit-rate stream is MPEG 4 which uses a system based on reference frames and delta frames to compress the image part of the video data. H.263 is another typical format that may be used. A video frame is selected as a reference frame and encoded in its entirety. Then a series of subsequent frames are selected, but for each of these frames, the only data that is encoded is that which has changed with respect to the previous frame. The encoded changes form what is known as the delta frame.

Whichever of the available compression formats are used, compression is governed by a series of parameters 24. This allows the compression level to be raised

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or lowered depending on the data rate required and the quality of picture desired. A greater level of compression gives a lower quality of data at a lower data rate and a lower level of compression gives a higher quality of data at a higher data rate.

In the embodiment of Fig. 2 a channel capacity measurement 26 is received from a channel 28 over which the transmission occurs. The measurement may be received from a receiving client who simply reports the received data rate. If the received data rate is reported to be lower than the rate at which data is being sent then it is assumed that data is being produced too fast for the channel and the parameters 24 are altered to increase the compression level until the data output rate is the same as the channel rate. Conversely, if the data rate rises at the receiving end, the parameters 24 may be altered to reduce the compression level and increase the output data rate.

Reference is now made to Fig. 3, which is a generalized block diagram showing a second embodiment of the present invention in which a series of compressed datastreams are continually created and are selected for use in individual channels according to measured parameters of the channel. Parts that are the same as those mentioned in previous embodiments are given the same reference numerals and are not referred to again except as necessary for an understanding of the present embodiment.

In the embodiment of Fig. 3, an input datastream is received from a source 20 as before. The stream is passed to a channel manager 30, which compresses the input datastream. However, instead of compressing it once only, it compresses it into a plurality of output data streams, each one using different compression parameters so as to produce a plurality of streams each having a different data rate. The various streams are then passed to one or more downlink managers 32.1...32.n, each of which is able to manage a limited number of channels 28 for sending output data to a limited number of targets 34. Each target 34 is associated with a client 36, typically client software located at the target 34, which is able to send back, to the downlink manager 32, feedback data such as the received channel rate.

The downlink manager 32 simply obtains the received channel rate from the client 36 and mixes the various streams from the channel manager to produce an average stream rate which matches the channel rate as closely as possible. For example if the received channel rate is 39.5 kbits/sec and the downlink manager has available a 35 kbits/sec stream and a 45 kbits/sec stream then the downlink manager

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will attempt to mix the two streams in suitable proportions to match the 39.5 kbits/sec channel. Thus the target 36 may receive a continuous stream of data, the quality of the channel influencing only the quality of the data and not the continuity.

It will be recalled that the compression systems in use include reference and delta frame style compression. Such compression systems, when used to produce streams at different data rates, do not produce delta frames which are interchangeable between the different data rates. Thus in order to create streams that are interchangeable, it is preferable to arrange all of the streams as a series of self-contained packets of given time duration. Each of the packets is self-contained in that it begins with a reference frame and hence does not depend on previously transmitted data. Thus the target is able to use consecutive packets from different streams without any data discontinuity.

The self-contained units are preferably of relatively short duration. The shorter the duration the better the system is able to follow dynamically changes in the bandwidth of the connection. On the other hand, since each unit must start with a reference or key frame, and such frames are very costly in bandwidth since they must be transmitted in full, the use of short self-contained units itself increases the required bandwidth. A compromise unit length of less than ten seconds, preferably 3, 5 or 7 seconds, is preferred.

In an alternative embodiment the length of the self-contained unit is itself allowed to vary dynamically in accordance with circumstances. When the downlink manager 32 detects a significant change in the channel bandwidth it issues a request for a new data rate from the channel manager 30. Alternatively, a new target may be requesting the data feed. The channel manager 30 initiates a time delay when a first request is received, the delay being less than ten seconds, as discussed above, and at the end of the delay starts new self-contained units at all data rates. Thus dynamic following of changes in bandwidth is provided whilst transmitting the minimum possible number of key or reference frames. If no request is received, then the system continues to use delta frames as long as it is practical.

In a variation of the above, instead of waiting to the end of the time delay, the channel manager first of all looks ahead at the approaching data stream and checks whether there is a reference frame approaching during the time delay period in any case. If so, no further action is needed. If there is no reference frame then the channel manager looks ahead to find the biggest delta frame, representing the biggest

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instantaneous change in the picture, over the delay time period. A reference frame is then inserted in place of the identified largest delta frame. Thus, the insertion of a full reference frame is optimized to the data.

Reference is now made to Fig. 4 which is a generalized block diagram showing the channel manager 30 and a part of a downlink manager 32 of Fig. 3 in greater detail. Parts that are the same as those mentioned in previous embodiments are given the same reference numerals and are not referred to again except as necessary for an understanding of the present embodiment.

As shown in Fig. 4, the channel manager 30 comprises a series of compression units 40.1, 40.2, 40.3, etc. Each of these compression units is preferably operative to compress an input signal received from source 20, using a different compression parameter or set of compression parameters to produce an output having a different data rate. Each compression unit is followed by a buffer 41. The buffer 41 may be used to arranged the compressed data into packets of fixed time duration.

The downlink manager 32 comprises a series of selector switches 42, one for each channel being managed. For the sake of simplicity, only one such switch 42 is shown in the figure. The switch 42 receives each one of the data streams produced by the source 20 and selects one of them at any given time to be sent to the channel 28. Selection is carried out based on a channel capacity measurement 44, which is received from the client 36.

Reference is now made to Fig. 5, which is a generalized block diagram showing a third embodiment of the present invention in which the user is able to set a quality level of the data that is being sent. Parts that are the same as those mentioned in previous embodiments are given the same reference numerals and are not referred to again except as necessary for an understanding of the present embodiment. As described above, compression parameters are altered in order to change the data rate. Generally speaking, there are numerous parameters that can be set in order to alter the data rate, and there are numerous combinations of these parameters that can give the same data rate. For example, parameters that may be altered include:

the extent of image compression within an individual frame,

the number of frames per second to be transmitted,

the proportion of reference frames to delta frames, and

a balance between compression levels of different parts of the data – for example video data includes both sound and image. It is possible to increase a level

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of compression to the image and to decrease a level of compression to the sound or vice versa.

In Fig. 5, part of a channel manager 30 is shown as well as a switch 42 of a downlink manager. In the channel manager of the embodiment of Fig. 5, a series of data compressors 50 are provided for each required data rate. The data compressors are labeled high, medium and low, although in fact they are different compromises between compression parameters. For example "high" may indicate high image quality but low frame rate, whereas "low" may indicate low image quality but high frame rate. The selector switch 48 is the same as in the previous embodiment except that it now chooses channels based on two different items of information. One item of information is the received channel rate 44, which selects the data rate as before. The other item of information is a data quality request which is received from the target. This selects, within the given data rate, between the different quality levels.

Reference is now made to Fig. 6, which is a generalized schematic diagram of a quality level selection tool 60 for use by a user in selecting a quality level in the embodiment of Fig. 5. The selection tool 60 comprises a simple longitudinal bar 62 which may be marked with labels and numbers, and a slider 64 for moving along the bar 62. The bar shown in Fig, 6 indicates that the user may select different compromises between sound quality and image quality.

Reference is now made to Fig. 7, which is a generalized schematic diagram of another quality level selection tool 70 for use by a user in selecting a quality level in the embodiment of Fig. 5. The selection tool 70 is likewise in the form of a bar and slider but this time the choice is between high quality images at a low frame rate (marked "still") and low quality images at a high frame rate (marked "motion"). It will be appreciated that a low bandwidth "high" may yield a lower image quality than a high bandwidth "low" and vice versa.

Embodiments of the present invention thus provide a system and method in which the measured received data level of a channel is used to select a transmitted data rate so that full advantage may be taken of fluctuating channel capacity levels to send the highest possible quality multimedia data.

It is appreciated that certain features of the invention, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the invention

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which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable subcombination.

It will be appreciated by persons skilled in the art that the present invention is not limited to what has been particularly shown and described hereinabove. Rather the scope of the present invention is defined by the appended claims and includes both combinations and subcombinations of the various features described hereinabove as well as variations and modifications thereof which would occur to persons skilled in the art upon reading the foregoing description.

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Claims

1. A device for streaming of media file data to be sent over at least one channel having a dynamically variable bandwidth, comprising

an input for receiving media file data at a first rate,

a multiple stream creator for creating a plurality of streams of said media file data, each stream compressed to predetermined other rates, each stream comprising a series of autonomous compressed data units which are mutually compatible, and

a stream selector for dynamically matching a bandwidth of the channel to rates of said streams to send said data file as a combination of said autonomous units from said streams via said channel,

wherein said autonomous units have durations which are one of a group comprising fixed predetermined durations and durations determined by changes in said channel bandwidth.

2. A device according to claim 1, wherein said stream selector is operable to select a combination of said streams in succession said combination being chosen to produce an average stream rate over a period of time which matches said channel bandwidth.

3. A device according to claim 1, wherein said bandwidth of said channel is liable to vary dynamically and wherein said stream selector is operable to repeat said matching throughout said streaming operation.

4. A device according to claim 2, wherein said bandwidth of said channel is liable to vary dynamically and wherein said stream selector is operable to repeat said matching throughout said streaming operation.

5. A device according to claim 1, wherein said autonomous units match each other across said plurality of streams, thereby to enable switching between said streams.

6. A device according to claim 5, wherein said data file is arranged in said streams in a compressed media format utilizing reference frames and

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delta frames and wherein each autonomous unit is self-contained in respect of reference frames.

7. A device according to claim 1, wherein said channel is a cellular telephone channel.

8. A device according to claim 1, wherein said channel is an Internet channel.

9. A device according to claim 1, said predetermined other rate being different for each stream.

10. A device according to claim 1, said predetermined other rate being identical for a set of said streams, each stream in said set being assigned a different balance between quality and speed of said media.

11. A device according to claim 1, said media file comprising a plurality of media types, said predetermined other rate being identical for a set of said streams, each stream in said set being assigned a different balance between quality of said different media types.

12. A device according to claim 10, said streams in said set being selectable by a signal received from said channel.

13. A device according to claim 11, said streams in said set being selectable by a signal received from said channel.

14. A device according to claim 1, comprising a detector for detecting a change in the bandwidth of said at least one channel and operable to request a corresponding change in the data rate, and wherein the device is operable, upon receipt of said request, to set a delay, and to issue a reference frame within said delay.

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15. A device according to claim 14, operable to issue said reference frame at the end of said delay.

16. A device according to claim 14, operable to issue said reference frame at the occurrence of a largest detected interframe change within the time delay.

17. A multiple stream creator for receiving a data stream at a first data rate and converting said data stream into a plurality of data streams at a plurality of data rates, said creator comprising an input for receiving said data stream at said first data rate, and a plurality of outputs, each operable to receive said data stream at said first rate and to output said data stream at a predetermined rate individually set for each output as a series of autonomous units having a duration, and wherein said duration is one of a group comprising a fixed predetermined duration and a duration dynamically changeable in accordance with bandwidth conditions in a transmission channel.

18. A multiple stream creator according to claim 17, wherein said outputs each comprise data buffers.

19. A multiple stream creator according to claim 17, comprising a data stream processor for processing said data stream received at said first rate into said plurality of autonomous units, said autonomous units being synchronized blocks, thereby allowing said output streams to be mixed in said transmission channel to produce continuously usable output.

20. A multiple stream creator according to claim 17, wherein said received data stream is in an uncompressed data format and wherein said data is compressed into a compressed data format independently for each one of said output data streams.

21. A method of sending a datastream over a variable bandwidth channel comprising modifying a quantity of data to be injected into the channel to accord with a measured capacity of the channel, said method comprising the steps of

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compressing the datastream, using an algorithm having compression parameters, to produce a plurality of compressed datastreams each comprising reference frames and delta frames, each compressed datastream produced by using the algorithm together with different parameters, and

synchronizing reference frames between the compressed datastreams so that combinations of said compressed datastreams can be sent via said channel.

22. A method according to claim 21, wherein said step of synchronizing reference frames is carried out at intervals determined by a dynamic status of said channel bandwidth.

23. A method according to claim 21, wherein said step of synchronizing reference frames is carried out at predetermined intervals.

24. A method according to claim 21, wherein said combination of said compressed datastreams is selected substantially dynamically to match the measured capacity of the channel.

25. A method according to claim 22, wherein a change in bandwidth of a channel causes a request for commencement of a new autonomous unit, and wherein said request causes initiation of measurement of a time delay, and wherein a new autonomous unit is commenced within said time delay.

26. A method according to claim 25, wherein said new autonomous unit is commenced at the end of said time delay.

27. A method according to claim 25, comprising the step of determining the largest delta frame during the time delay and sending a reference frame, to initiate said new autonomous unit, in place of said determined largest delta frame.

28. A tool for controlling receipt of media file data over a network, wherein said media file data is available at a plurality of quality levels, the

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tool comprising a quality selector to enable a user to select between said different quality levels for receipt.

29. A tool according to claim 28, wherein said media file comprises a plurality of data groups and wherein each quality level is a different balance between quality levels of the plurality of data groups.

30. A tool according to claim 28, wherein said quality selector comprises a slider operable to be moved along a scale, the position of the slider on the scale indicating a quality level.

31. A device for streaming of media file data to be sent over at least one channel having a dynamically variable bandwidth, substantially as hereinbefore described with reference to the accompanying drawings.

32. A multiple stream creator for receiving a data stream at a first data rate and converting said data stream into a plurality of data streams at a plurality of data rates, substantially as hereinbefore described with reference to the accompanying drawings.

33. A method of sending a datastream over a variable bandwidth channel comprising modifying a quantity of data to be injected into the channel to accord with a measured capacity of the channel, substantially as hereinbefore described with reference to the accompanying drawings.

34. A tool for controlling receipt of media file data over a network, substantially as hereinbefore described with reference to the accompanying drawings.

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Application No: GB 0023062.3 **Examiner:** John Cullen
Claims searched: 1-27, 31-33 **Date of search:** 6 November 2001

Patents Act 1977
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Databases searched:

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Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A, E	EP 1049074 A1	(LUCENT) See Abstract, Figs. 2 and 4, and paragraphs 14-18 and 28-35.	---
A, E	WO 00/72601 A2	(BIGBAND NETWORKS) See Figs. 1-4, 6, 7 and 9, line 26 of p15 to line 24 of p17 and line 10 of p21 to line 2 of p22.	---
A	WO 99/00984 A1	(CITRIX) See Fig. 15 and line 13 of p30 to line 14 of p33.	---
A	WO 98/09387 A1	(ERICSSON) See Figs. 3A, 6 and 7, and line 35 of p14 to line 26 of p15.	---
A	US 5847760	(OPTIBASE) See whole document.	---

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

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PATENT ABSTRACTS OF JAPAN

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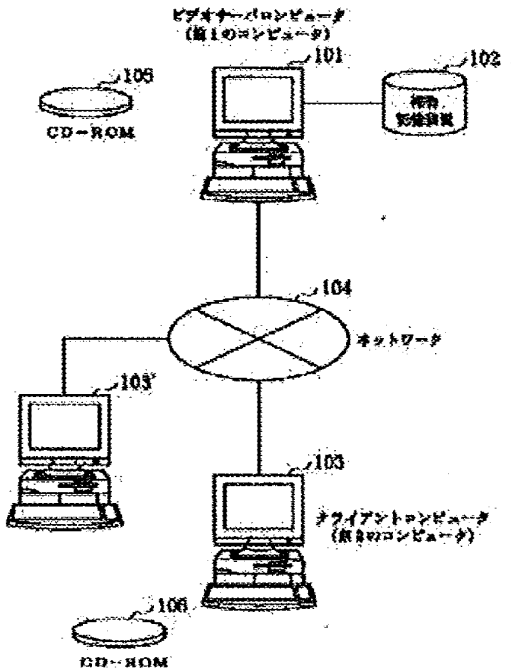
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(54) SYSTEM FOR DISTRIBUTING PICTURE DATA AND RECORDING MEDIUM USED FOR THE SAME

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a picture data distribution system capable of efficiently distributing picture data with appropriate quality in accordance with changes of the network connection environment of a client computer from moment to moment and a recording medium on which its program is recorded.
SOLUTION: This system has a 1st computer (image server computer 101) capable of distributing the picture data and one or more 2nd computers (client computer 103) receiving the picture data, and the 1st computer 101 receives a line situation notification message from the 2nd computer 103 and transmits the picture data (picture data extracted among a plurality of pieces of picture data which are preliminarily stored and have different compressibility or picture data compressed with optimum compressibility every time) which are subjected to compressibility being optimum to the communication speed of a line to which the 2nd computer is connected on the basis of the message.



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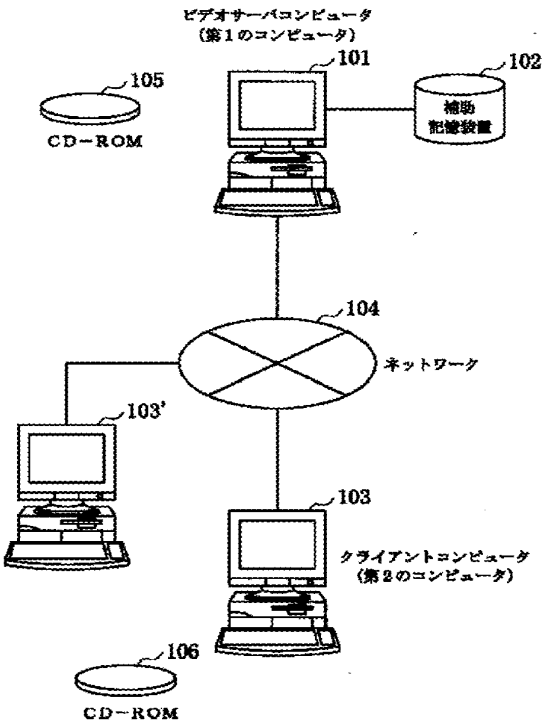
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最終頁に続く

(54)【発明の名称】　画像データ配信システムおよびそれに用いる記録媒体

(57)【要約】
【課題】　クライアントコンピュータのネットワーク接続環境の時々刻々の変化に応じて、適切な品質の画像データを効率よく配信することが可能な画像データ配信システムおよびそのためのプログラムを記録した記録媒体の提供。
【解決手段】　画像データを配信可能な第１のコンピュータ（画像サーバコンピュータ１０１）とその画像データを受信する１以上の第２のコンピュータ（クライアントコンピュータ１０３）を有し、第１のコンピュータ１０１は、第２のコンピュータ１０３から回線状況通知メッセージを受信し、そのメッセージに基づいて、第２のコンピュータが接続されている回線の通信速度に最適な圧縮を施した画像データ（予め記憶している圧縮率の異なる複数の画像データから抽出した画像データかまたはその都度最適な圧縮率で圧縮した画像データ）を送信する。



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【特許請求の範囲】

【請求項１】　画像データをストリーミング配信可能な第１のコンピュータとその画像データを受信する１以上の第２のコンピュータを有する画像データ配信システムにおいて、

前記第１のコンピュータは、

前記第２のコンピュータから回線状況通知メッセージに基づいて、該第２のコンピュータが接続されている回線の通信速度に最適な圧縮を施した画像データを送信する最適画像配信手段を有することを特徴とする画像データ配信システム。

【請求項２】　前記最適画像配信手段は、

送信時間を計測するタイマと、

圧縮率の異なる複数の画像データおよび該画像データ毎に該画像データの内容を識別可能な内部識別アドレスと送信の際の送信タイミングを規定するタイムスタンプとの対応データを保持する記憶手段と、

前記第２のコンピュータからの回線状況通知メッセージに基づいて前記記憶手段から最適な圧縮率の画像データを抽出するとともに、該抽出した画像データの、前記タイマで計測された送信時間に対応する前記内部識別アドレス以降の画像データ内容を配信する手段とを有することを特徴とする請求項１記載の画像データ配信システム。

【請求項３】　前記最適画像送出手段は、

１つの画像データを保持する記憶手段と、

前記第２のコンピュータから所定の時間間隔で受信する回線状況通知メッセージに基づいて、前記記憶手段に保持されている１つの画像データから、該第２のコンピュータが接続されている回線に最適な圧縮率の画像データを動的に作成して配信する手段とを有することを特徴とする請求項１記載の画像データ配信システム。

【請求項４】　前記第１のコンピュータは、画像サーバコンピュータであり、前記第２のコンピュータは、クライアントコンピュータであることを特徴とする請求項１または請求項２記載の画像データ配信システム。

【請求項５】　請求項１または２記載の第１のコンピュータにおける各手段および第２のコンピュータにおける各手段を実現する処理をプログラムコード化して記憶したことを特徴とするコンピュータで読み取り可能な記録媒体。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、ネットワーク上でビデオストリーミングデータを送信する場合におけるデータ作成および配信システムに関し、特にデータを要求するクライアントコンピュータのネットワーク接続環境の動的な変化に対応して最適なビデオデータ配信を実現するビデオデータ配信システムおよびそのためのプログラムを記録した記録媒体に関する。

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【０００２】

【従来の技術】ネットワーク上における一般的なビデオデータ配信においては、ビデオサーバコンピュータはクライアントコンピュータのデータ送信要求に対し該当するデータのストリーミング配信を行なっている。通常のビデオデータは非常にサイズが大きいため、回線上に大きな帯域幅を必要としていた。従って、従来は、限られたネットワーク内において回線の帯域幅を考慮し適切な圧縮を行うことにより、ビデオデータ配信が行われていた。

【０００３】しかし、近年のインターネット技術の普及に伴い、インターネットを利用したビデオ配信システムが多数考案されている。インターネットを利用した場合、インターネットに接続され世界中に点在する膨大な数のコンピュータがクライアントコンピュータとなり得る。そのため、クライアントコンピュータのネットワーク接続環境はクライアントコンピュータ毎に異なることとなる。

【０００４】従って、例えば高品質（低圧縮率）のビデオデータを配信した場合、帯域幅の狭い通信回線に接続しているクライアントコンピュータは、配信された全てのビデオデータを受信しきれなくなる。この理由により、インターネット上でビデオ配信を行なう場合には、できるだけ多くのクライアントコンピュータで受信可能となるように、帯域幅の狭い通信回線に合わせた低品質（高圧縮率）のビデオデータを配信するようにしていた。この環境においては、高品質のビデオデータの受信可能なクライアントコンピュータであっても品質の低いビデオデータを受信することに甘んじなければならなかった。

【０００５】この問題点に関するものとして、ビデオサーバが、予め記憶装置に格納してある中間形態の動画データを事前に高品質および低品質の複数のデータを準備し、さらにビデオデータを要求するクライアントコンピュータが接続されている回線の通信速度を取得する手段を具備し、取得した通信速度により最適なデータを配信する仕組みが考案されている。

【０００６】

【発明が解決しようとする課題】しかしながら、一般に、クライアントコンピュータのネットワーク接続環境すなわち帯域幅は回線の混雑の度合等により刻々と変化するものであるが、上記従来技術においては、動画データの配信要求のあったクライアント端末のネットワーク性能（伝送速度）を検知し、それに応じた圧縮率の動画データを送信するものであり、ネットワーク性能の時々刻々の変化に応じて送信ビデオデータの品質（データ圧縮率）を変化させるものとはなっていない。

【０００７】本発明の目的は、クライアントコンピュータのネットワーク接続環境すなわち帯域幅の時々刻々の変化に応じて、適切な品質の画像データを効率よく配信

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することが可能な画像データ配信システムおよびそのためのプログラムを記録した記録媒体を提供することである。

【０００８】

【課題を解決するための手段】本発明は、上記目的を達成するために、画像データをストリーミング配信可能な第１のコンピュータ（好ましくは画像サーバコンピュータ）とその画像データを受信する１以上の第２のコンピュータ（好ましくはクライアントコンピュータ）を有する画像データ配信システムにおいて、第１のコンピュータは、第２のコンピュータから回線状況通知メッセージに基づいて、第２のコンピュータが接続されている回線の通信速度に最適な圧縮を施した画像データを送信する最適画像配信手段を有することを特徴としている。

【０００９】なお、前記最適画像配信手段は、（ａ）送信時間を計測するタイマと、圧縮率の異なる複数の画像データおよび該画像データ毎に該画像データの内容を識別可能な内部識別アドレスと送信の際の送信タイミングを規定するタイムスタンプとの対応データを保持する記憶手段と、第２のコンピュータからの回線状況通知メッセージに基づいて記憶手段から最適な圧縮率の画像データを抽出するとともに、該抽出した画像データの、タイマで計測された送信時間に対応する内部識別アドレス以降の画像データ内容を配信する手段とを有するか、あるいは、（ｂ）１つの画像データを保持する記憶手段と、第２のコンピュータから所定の時間間隔で受信する回線状況通知メッセージに基づいて、記憶手段に保持されている１つの画像データから、第２のコンピュータが接続されている回線に最適な圧縮率の画像データを動的に作成して配信する手段とを有している。

【００１０】また、本発明の記録媒体は、前記第１のコンピュータ（画像サーバコンピュータ）における各手段および第２のコンピュータ（クライアントコンピュータ）における各手段を実現する処理をプログラムコード化してコンピュータ読み取り可能なＣＤ－ＲＯＭ，ＤＶＤ，ＦＤなどの記録媒体に記録したものである。

【００１１】

【発明の実施の形態】以下、本発明の好ましい実施の形態を説明する。画像データを配信する機能を有するネットワークに接続されている画像配信サーバを具備し、該画像配信サーバは画像データを格納可能な記憶装置を具備し、画像配信サーバにアクセス可能な不特定多数のクライアントコンピュータを具備する構成とする。

【００１２】配信するビデオデータ作成において、ビデオサーバコンピュータは、オリジナルビデオデータを基に、高品質から低品質まで複数のビデオデータを記憶装置に作成し、個々のビデオデータに対し一定時間間隔のタイムスタンプを付加する機能を具備する。

【００１３】また、ビデオデータを受信するクライアントコンピュータでは、ビデオデータ受信中に受信パケットの状態を監視し、損失パケットが一定の基準を超えた場合、クライアント側の通信回線に十分な帯域が確保されていないと判定し、また、一定の基準時間の間に損失パケットが無い場合は、クライアント側の通信回線に十分な帯域が確保されていると判定し、その判定結果を配信中のビデオサーバコンピュータへ送信する手段を具備する。

【００１４】上述の判定結果を受信したビデオサーバは、その判定結果に適切な品質のビデオデータファイルを選択し、現在配信中のビデオデータファイルの切り換えを行う。その際、切り換え前後の２つのビデオデータに付加されているタイムスタンプを参照し、配信を中止する時点でのタイムスタンプと同様のタイムスタンプを持つ時点より切り換え後のビデオデータの配信を開始する機能を具備する。

【００１５】また、上記目的を達成するために、本発明は、ビデオデータを配信する機能を有するネットワークに接続されているビデオサーバコンピュータを具備し、さらにその記憶装置に記憶されているオリジナルビデオデータを送信時に所定の圧縮率で圧縮しながら配信する機能を具備する構成とする。

【００１６】ビデオデータを受信する際において、クライアントコンピュータは、ビデオデータ受信中に受信パケットの状態を監視し、損失パケットが一定の基準を超えた場合クライアント側の通信回線に十分な帯域が確保されていないと判定し、また、一定の基準の時間、損失パケットが無い場合、クライアント側の通信回線に十分な帯域が確保されていると判定し、その判定結果を配信中のビデオサーバコンピュータへ送信する手段を特徴とする機能を具備する。

【００１７】さらに、上述の判定結果を受信したビデオサーバコンピュータは、その判定結果に従い、動的に圧縮率に変更し、その変更された圧縮率で圧縮されたビデオデータを配信する機能を具備する。

【００１８】上記構成を採用することにより、配信されるビデオデータは、受信するクライアントコンピュータのネットワーク接続環境に従い配信するビデオデータの品質を動的に変化させることができる。これにより、クライアントコンピュータは常に最適化されたビデオデータを見掛け上切れ目なく受信することが可能となる。

【００１９】また、本発明の記録媒体は、上記の如きクライアントコンピュータが行う処理やビデオサーバコンピュータが行う処理をプログラムコード化してコンピュータ読み取り可能なＣＤ－ＲＯＭ，ＤＶＤ，ＦＤなどの記録媒体に記録したものである。

【００２０】（実施例の説明）以下、本発明の実施例として、２つの実施例を説明する。図１は、第１の実施例および第２の実施例における共通のハードウエア構成を示すブロック図である。本発明は、圧縮して配信することが可能な全てのデータ（特に画像データ）に対して適

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用可能であるが、本実施例では、ビデオデータ（動画データ）を例にとって説明する。

【００２１】図１において、１０１はビデオデータの作成および配信を行なうビデオサーバコンピュータ、１０２はビデオデータを格納する補助記憶装置、１０３および１０３’はクライアントコンピュータ、１０４はビデオサーバコンピュータ１０１とクライアントコンピュータ１０３が接続されるネットワーク環境である。以下の説明では、１つのサーバコンピュータと１つ以上のクライアントコンピュータからなるクライアント・サーバシステムの場合を用いて説明するが、第１のコンピュータから第２のコンピュータへの２つのコンピュータ間でのデータの配信にも適用可能であることはいうまでもない。

【００２２】（第１の実施例）まず、第１の実施例について図２～図６を用いて説明する。図２は、記憶装置に格納する圧縮ビデオデータファイルのファイル構造の説明図である。図２において、２０３は圧縮ビデオデータファイルのヘッダ情報、２０４は本実施例で取り上げる画像データファイル、２０５はＥＯＦ（ＥＯＦ：End of File）を示す。また、２０１は本発明の特徴である圧縮ビデオデータファイルのタイムスタンプであり、２０２は、タイムスタンプ２０１と対応する圧縮ビデオデータファイルの内部識別アドレスである。なお、本実施例で取り上げる圧縮率の異なる他の画像ファイル（圧縮画像ファイルＢおよび圧縮画像ファイルＣ）構造も図２と同様である。内部識別アドレス２０２は、ファイル毎にタイムスタンプ１０２に対応して設けられるものであるが、ファイルの品質（圧縮率）が異なればそれに伴って異なる値を有する。

【００２３】図３は、同一画像ファイルから生成された圧縮率の異なる３種類の圧縮ビデオデータファイルのヘッダ情報の説明図である。同図（ａ）は低圧縮画像ファイルＡのヘッダ情報を、同図（ｂ）は中圧縮画像ファイルＢのヘッダ情報を、同図（ｃ）は高圧縮画像ファイルＣのヘッダ情報を示している。３０１はタイムスタンプ情報、３０２は、インデックスに対応する図２に示すファイルの内部識別アドレスである。

【００２４】図４は、圧縮率の異なる３つの画像ファイルとタイムスタンプと内部識別アドレスの関係を説明するための図である。同図（ａ）は、低圧縮画像ファイルＡとタイムスタンプと内部識別アドレスの関係を、同図（ｂ）は中圧縮画像ファイルＢとタイムスタンプと内部識別アドレスの関係を、同図（ｃ）は高圧縮画像ファイルＣとタイムスタンプと内部識別アドレスの関係を、それぞれ示している。本例では、説明を簡単にするために、同図（ａ）に示す低圧縮画像ファイルＡを１／２に圧縮したものを中圧縮ファイルＢとして同図（ｂ）に示し、さらにこれを１／２に圧縮したものを高圧縮画像ファイルＣとして同図（ｃ）に示すとともに、タイムスタンプ，内部識別アドレスと圧縮画像ファイルＡ～Ｃの内容の関係がわかりやすいように画像ファイル中に「い」、「ろ」、「は」・・・などを便宜的に示した。

【００２５】図５は、ビデオサーバコンピュータ１０１に保持される、通信速度と該通信速度に最適化された圧縮画像ファイルとの対応図である。図５における通信速度を表わす記号（ｍ、ｎ）の大小関係は、ｍ＜ｎとする。同図に示すように、通信速度が低速の場合は（～ｍ）、低品質である高圧縮画像ファイルＣを、通信速度が高速の場合は（ｎ～）、高品質である低圧縮画像ファイルＡを配信するようにする。

【００２６】図６および図７は、第１の実施例の動作を説明するためのフローチャートである。まず、ビデオデータを配信するビデオサーバコンピュータ１０１の動作を、図６を用いて詳細に説明する。

【００２７】図６において、クライアントコンピュータ１０３からのデータ要求に従い、該当する記憶装置内のビデオデータ（システムには初期配信ファイルが設定済とする。本実施例では、初期配信ファイルは「中圧縮画像ファイルＢ」とする）の配信を開始し、かつ配信時間の計測を開始する（ステップ６０１）。

【００２８】クライアントコンピュータ１０３から低品質データの受信要求（後述する図７のステップ７０６参照）があった場合（ステップ６０３）、図５の対応図に従い、現在送信中のファイル（ファイルＢ）より１段階品質の劣る「高圧縮画像ファイルＣ」を送信ファイルとして確定する（ステップ６０４、６０５）。

【００２９】次に現在時点の配信時間を測定する（ステップ６０６）。本実施例では、この時の測定時間が４ｍｓであったと仮定し、図３に示すヘッダ情報より、「ファイルＢ」の４ｍＳの開始内部識別アドレスは「iiii」と確定する（ステップ６０７）。すなわち、画像「い」、「ろ」は配信済みとする。ビデオサーバコンピュータ１０１は即座に配信中の「中圧縮画像ファイルＢ」の配信を中止し、内部識別アドレス「iiii」から「高圧縮画像ファイルＣ」の画像「は」、「に」、・・・の配信を開始する（ステップ６０８）。

【００３０】逆に、クライアントコンピュータ１０３より高品質データの受信要求（後述する図７のステップ７０７参照）があった場合（ステップ６０３：Ｙ）、図５の対応図に従い、現在配信中の「中圧縮画像ファイルＢ」より１段階品質の高い「低圧縮画像ファイルＡ」を次送信ファイルとして確定する（ステップ６０４、６０５）。以下の動作は同様である。すなわち、ビデオサーバコンピュータ１０１は即座に配信中の「中圧縮画像ファイルＢ」の配信を中止し、内部識別アドレス「iiii」から「低圧縮画像ファイルＡ」の画像「は」、「に」、・・・の配信を開始する（ステップ６０８）。

【００３１】なお、現時点での配信データが「高圧縮画像ファイルＣ」であった場合にさらに低品質の高圧縮の

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画像ファイルが要求された場合、図５より１段階品質の劣るビデオデータは存在しないことがわかる。また、現時点での配信データが「低圧縮画像ファイルＡ」であった場合にさらに高品質の低圧縮画像ファイルが要求された場合にも、図５より１段階品質の高いビデオデータは存在しないことがわかる。このような場合は、データの存在しない旨のメッセージを送信し、現時点でのデータ配信を続行する（ステップ６０９）。

【００３２】また、ビデオサーバコンピュータ１０１は、ビデオデータの終端すなわち図２に示す「ＥＯＦ」まで配信を行った場合（ステップ６０２：Ｙ）、データの配信を終える。

【００３３】次に、ビデオデータを受信するクライアントコンピュータ１０３の動作を、図７を用いて詳細に説明する。図７において、先ず、ビデオサーバコンピュータ１０１に対するビデオデータ要求により、ビデオサーバから送信されたデータの受信を開始し、同時に損失パケット監視タイマをリセットする（ステップ７０１）。

【００３４】損失パケット数がシステムに既設定済の数を超過した場合（ステップ７０２：Ｙ）、クライアントコンピュータ側の通信回線に十分な帯域が確保されていないと判断し、ビデオサーバに低品質データの要求メッセージを送信する（ステップ７０６）。損失パケット数がシステムに既設定済の数を超過しない場合（ステップ７０２：Ｎ）、損失パケットの発生を常に監視し（ステップ７０３）、損失パケットが発生した場合（ステップ７０３：Ｙ）、損失パケット監視タイマをリセットする（ステップ７０４）。

【００３５】この損失パケット監視タイマが、システムに既設定済の一定時刻を超過した場合、すなわち損失パケットが一定時間発生しなかった場合（ステップ７０３：Ｎ，７０５：Ｙ）、クライアントコンピュータ１０３側の通信回線に十分な帯域が確保されており現在受信中のビデオデータよりも高品質なデータ（低圧縮のデータ）の受信が可能と判断し、ビデオサーバコンピュータ１０１に高品質データの要求メッセージを送信する（ステップ７０７）。ステップ７０８では、ビデオサーバコンピュータ１０１からの配信データに従い今までと異なる品質の配信データを受信し、同時に損失パケット監視タイマをリセットする。

【００３６】ここで、図６のステップ６０９に示すデータ無しのメッセージを受信した場合、そのメッセージに従い、低品質データ無しの場合はステップ７０６の低品質データ要求メッセージ送信を、また、高品質データ無しの場合はステップ７０７の高品質データ要求メッセージ送信を中止する。なお、クライアントコンピュータ１０３はビデオデータの終端をしめす「ＥＯＦ」まで受信した場合（ステップ７０９：Ｙ）、受信動作を終了する。

【００３７】最後に、ビデオデータフォーマットについて詳述する。本実施例における配信ビデオデータのフォーマットは、図２に示すようにヘッダ情報部分（２０３）とデータ部分（２０４）とから構成され、ヘッダ部分には、図３に示すような、タイムスタンプ毎のアドレスが保持されている。ビデオサーバによりビデオデータを圧縮する際に、ヘッダ部分を生成し付加する。なお、図２および図３における２０１と３０１、２０２と３０２は同値である。

【００３８】以上、第１の実施例は、オリジナルなビデオデータを基に高品質（低圧縮）から低品質（高圧縮）まで、品質の異なる複数のビデオデータをビデオサーバの記憶装置に記憶しておき、クライアントコンピュータからの配信要求に対し、クライアントコンピュータにおける受信状態に応じて、最適な品質のビデオデータを動的に切替えながら配信するものである。

【００３９】（第２の実施例）次に説明する第２の実施例は、ビデオサーバに保持するビデオデータは、オリジナルなもの１種類のみとし、サーバから配信するビデオデータの圧縮を、クライアントコンピュータにおける受信状態に応じて動的に最適化するものである。

【００４０】以下、本第２実施例のビデオサーバ側の処理を、図８を用いて詳細に説明する。同図において、まず、クライアントコンピュータからのデータ要求に従い、該当する記憶装置内のオリジナルビデオデータをビデオサーバに取り出し（ステップ８０１）、圧縮を行いながら（システムには初期圧縮レートが設定済とする。）送信する（ステップ８０３）。クライアントコンピュータ１０３より低品質データ要求または高品質データ要求のメッセージ受信があった場合（ステップ８０４）、圧縮レートを変更する（ステップ８０５）。

【００４１】なお、ビデオサーバコンピュータ１０１はビデオデータの終端まで配信した場合（ステップ８０２）、配信動作を終了する。

【００４２】ビデオデータを受信するクライアントコンピュータの動作は、第１の実施例と同様のため詳細な説明は省略する。

【００４３】なお、上記の如き、ビデオサーバコンピュータが行う各処理手順およびクライアントコンピュータが行う各処理手順を、ＣＤ－ＲＯＭ，ＤＶＤ，あるいはＦＤなどの記録媒体に一緒にまたは別々に記録して市場に流通させることができる。利用者は、この記録媒体をビデオサーバコンピュータとクライアントコンピュータにインストールすることにより、本発明を簡単に利用することが可能になる。

【００４４】

【発明の効果】以上詳細に説明したように、本発明によれば、ビデオサーバにより配信されるビデオデータは、受信するクライアントコンピュータのネットワーク接続環境に従い動的に変化させることが実現できる。これにより、クライアントコンピュータは常に最適化されたビ

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デオデータを見掛け上切れ目なく受信することが可能となる。

【図面の簡単な説明】

【図１】本発明の第１の実施例および第２の実施例における共通のハードウエア構成を示すブロック図である。

【図２】記憶装置に格納する圧縮ビデオデータファイルのファイル構造の説明図である。

【図３】同一画像ファイルから生成された圧縮率の異なる３種類の圧縮ビデオデータファイルのヘッダ情報の説明図である。

【図４】圧縮率の異なる３つの画像ファイルとタイムスタンプと内部識別アドレスの関係を説明するための図である。

【図５】ビデオサーバコンピュータに保持される、通信速度と該通信速度に最適化された圧縮画像ファイルとの対応図である。

【図６】第１の実施例におけるビデオサーバコンピュータの動作を説明するためのフローチャートである。

【図７】第１の実施例におけるクライアントコンピュータの動作を説明するためのフローチャートである。

【図８】第２の実施例におけるビデオサーバコンピュータの動作を説明するためのフローチャートである。

【符号の説明】

１０１：ビデオデータの作成および配信を行なうビデオサーバコンピュータ（第１のコンピュータ）

１０２：ビデオデータを格納する記憶装置

１０３，１０３’：ネットワークと接続されるクライアントコンピュータ（第２のコンピュータ）

１０４：ビデオサーバコンピュータとクライアントコンピュータが接続されるネットワーク環境

１０５：プログラム記録媒体（ＣＤ－ＲＯＭ）

１０６：プログラム記録媒体（ＣＤ－ＲＯＭ）

２０１：圧縮ファイルのタイムスタンプ

２０２：圧縮ファイルのタイムスタンプに対応した内部識別アドレス

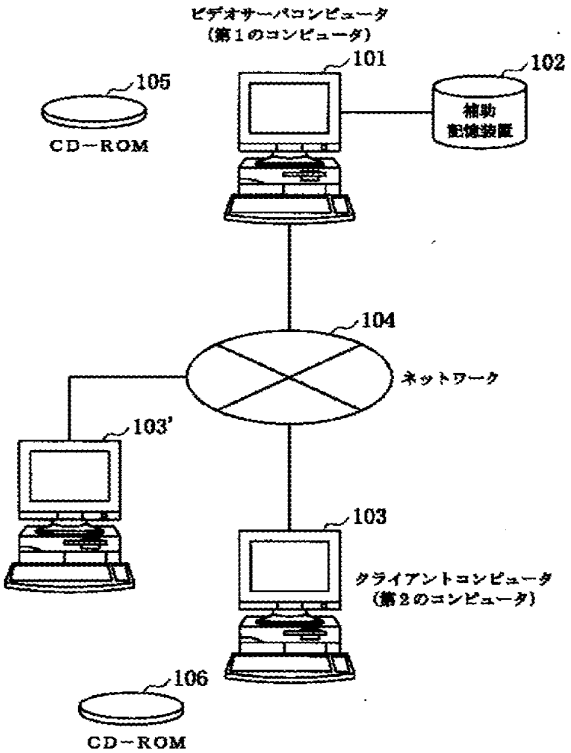
２０３：圧縮ファイルのファイルのヘッダ情報

２０４：本実施例で取り上げるファイルＡのファイルフォーマット

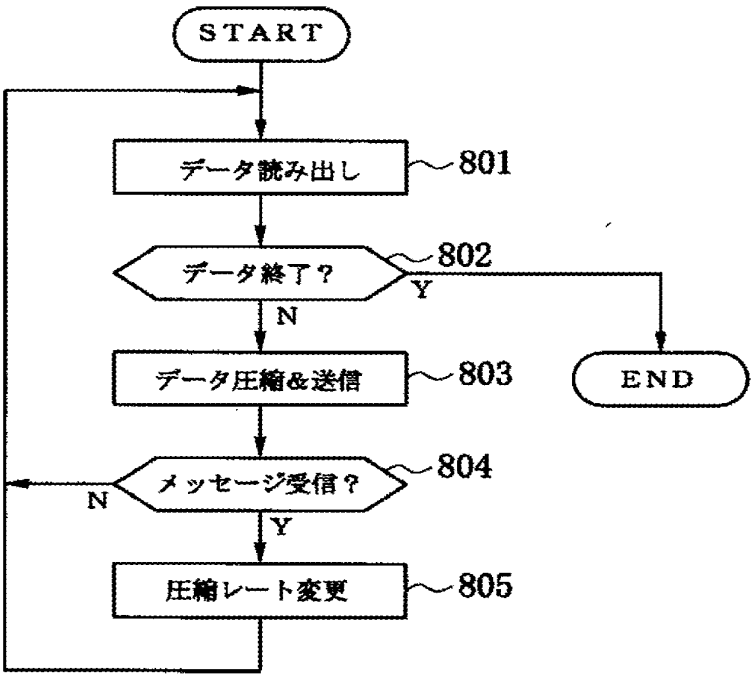
３０１：圧縮ファイルヘッダのタイムスタンプ情報

３０２：圧縮ファイルヘッダのタイムスタンプ情報に対応する内部識別アドレス

【図１】



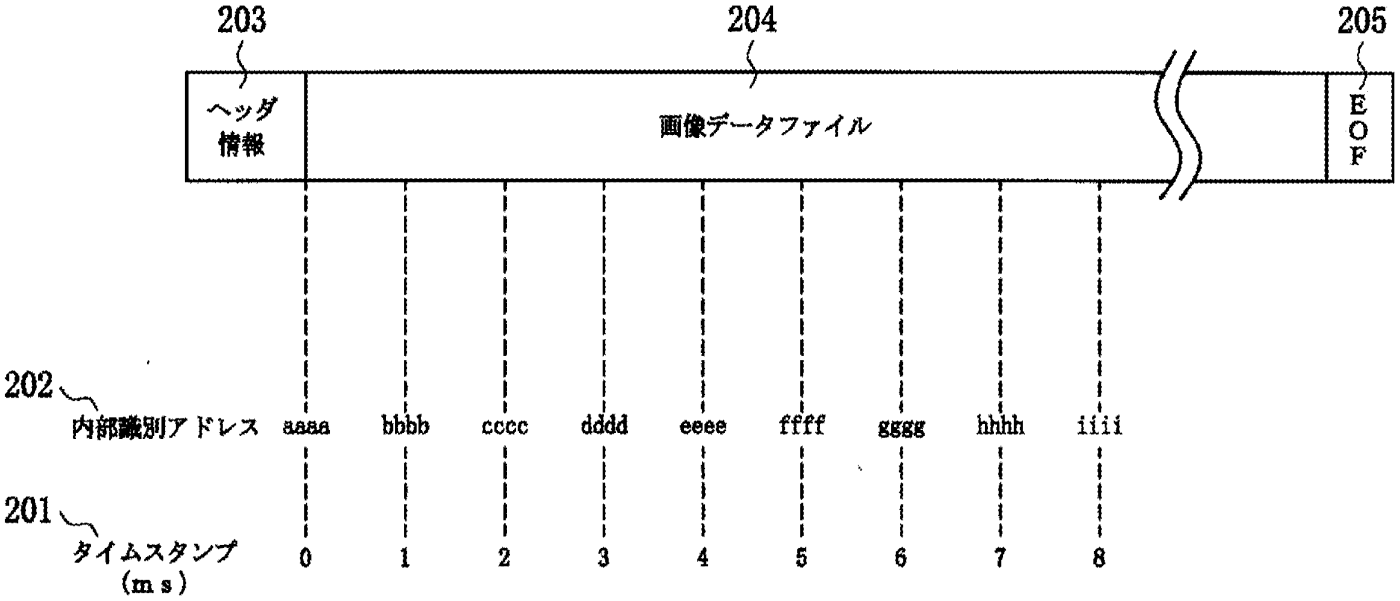
【図８】



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【図２】

画像データファイルのフォーマット



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【図３】

ヘッダ情報の構造

301 タイムスタンプ	302 内部識別アドレス
0	a a a a
1	b b b b
2	c c c c
3	d d d d
4	e e e e
5	f f f f
6	g g g g
7	h h h h
8	i i i i
:	:

低圧縮
画像ファイル（A）
（a）

301 タイムスタンプ	302 内部識別アドレス
0	a a a a
1	c c c c
2	e e e e
3	g g g g
4	i i i i
5	k k k k
6	m m m m
7	o o o o
8	q q q q
:	:

中圧縮
画像ファイル（B）
（b）

301 タイムスタンプ	302 内部識別アドレス
0	a a a a
1	e e e e
2	i i i i
3	m m m m
4	q q q q
5	u u u u
6	y y y y
7	:
8	:
:	:

高圧縮
画像ファイル（C）
（c）

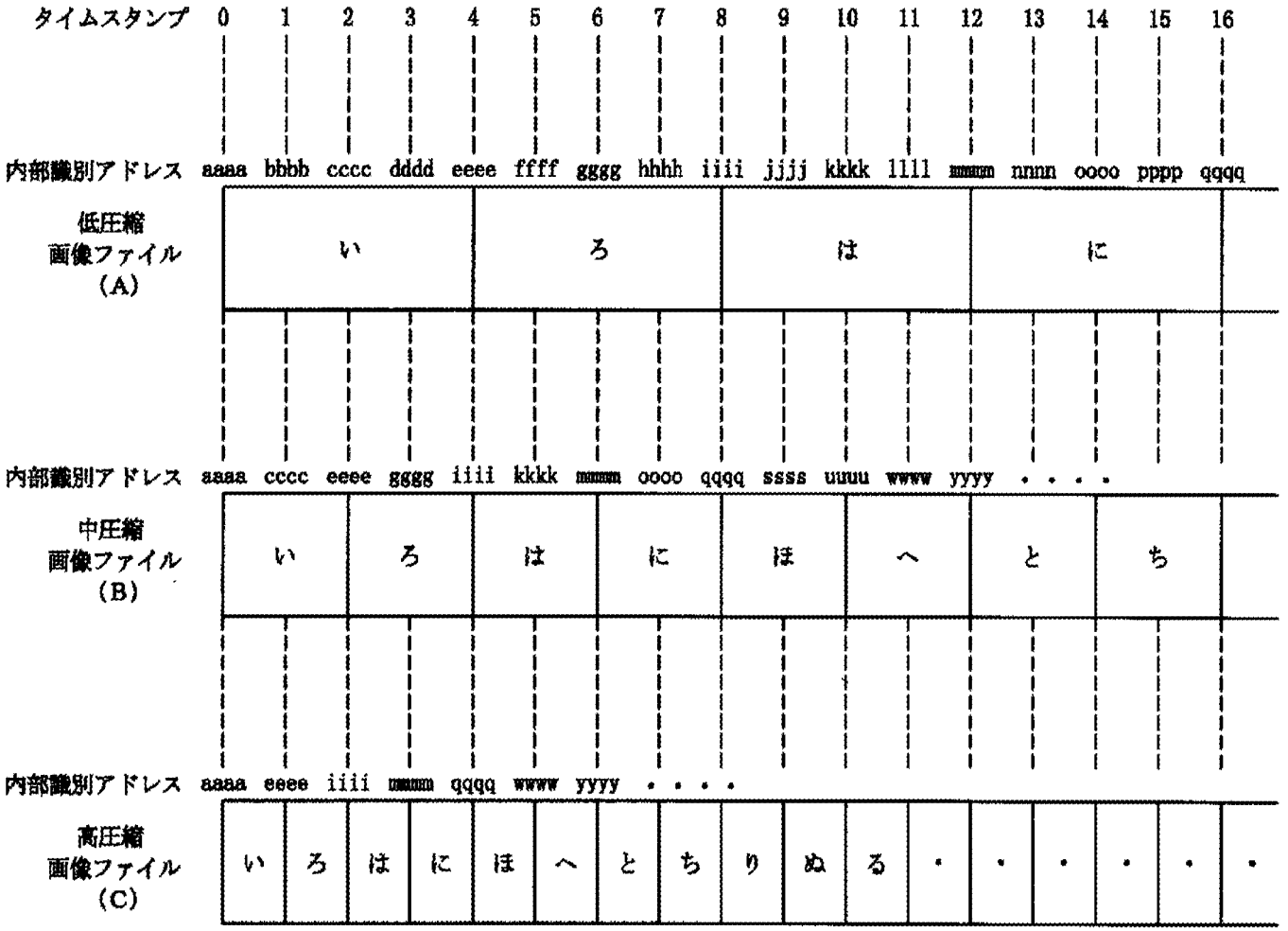
【図５】

通信速度と対応圧縮ファイル

項番	通信速度（ｂｐｓ）	ファイル名
1	～m	圧縮画像ファイルC
2	m～n	圧縮画像ファイルB
3	n～	圧縮画像ファイルA

通信速度の大小関係　m＜n

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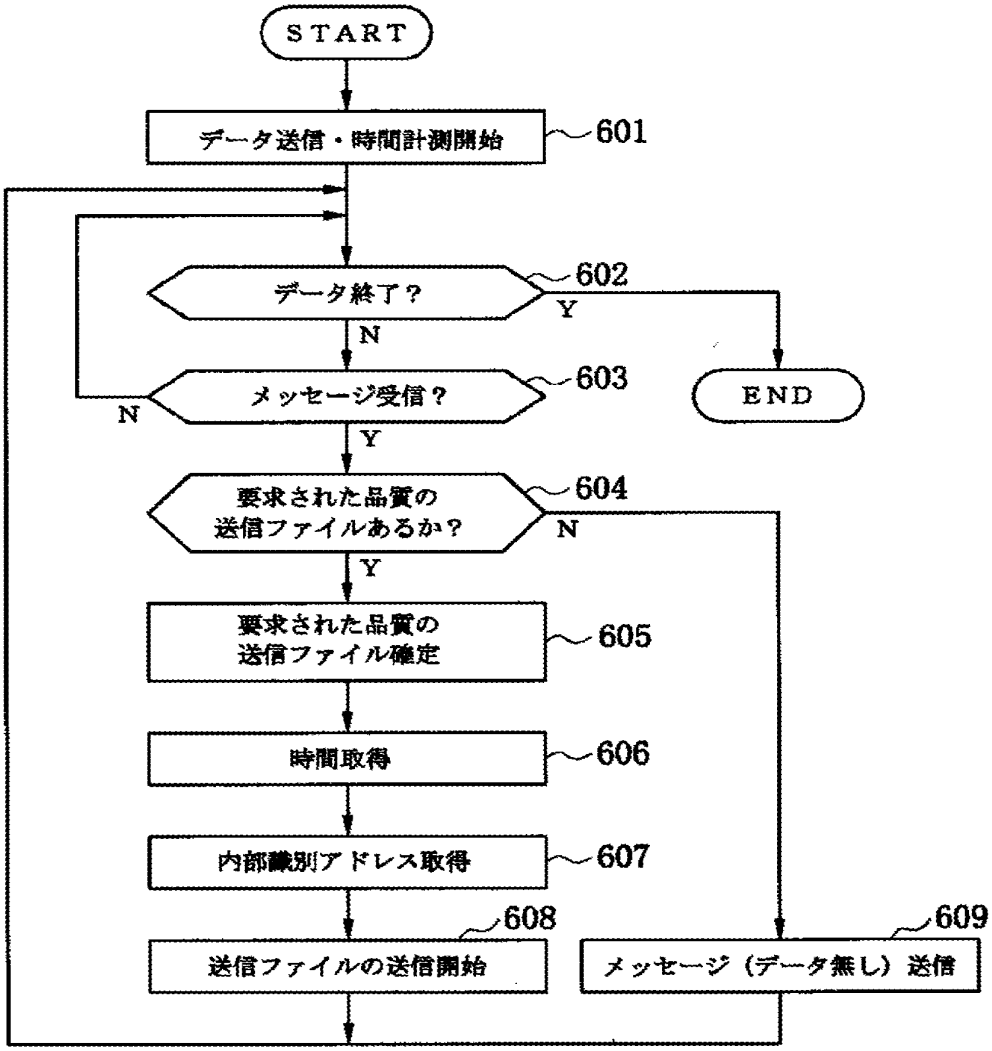
【図４】

特開２００１－９２７５２

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【図６】

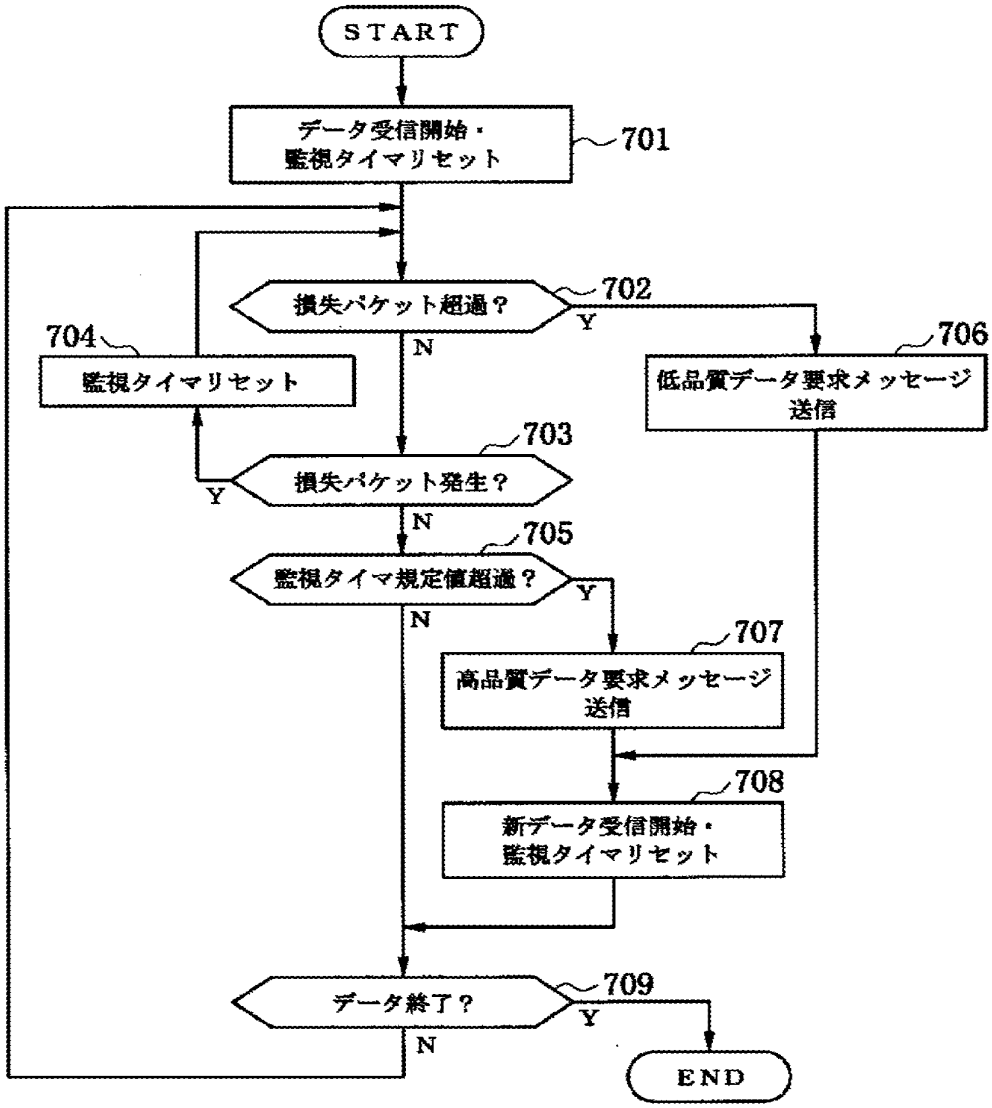
（ビデオサーバコンピュータの処理）



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【図７】

(クライアントコンピュータの処理)



フロントページの続き

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会社日立情報システムズ内

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5B089 GA11 JA33 JB03 JB22 KA05
KA12 KB06 KB11 KC28 KC53
KC59 KC60 KH28
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UA02 UA38
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Electronic Patent Application Fee Transmittal

Application Number:	16252188
Filing Date:	18-Jan-2019
Title of Invention:	APPARATUS, SYSTEM, AND METHOD FOR MULTI-BITRATE CONTENT STREAMING
First Named Inventor/Applicant Name:	DAVID F. BRUECK
Filer:	Brett Carlson/Julie Graf
Attorney Docket Number:	066.0141X1C7

Filed as Large Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
SUBMISSION- INFORMATION DISCLOSURE STMT	1806	1	240	240
		Total in USD ($)		**240**

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(54) A method of transmitting data streams with data segments of variable length

(57) A method of transmitting data streams between a sending host and a receiving host using a transport protocol comprising the steps of making available data streams at the sending host in the form of mono-rate or multi-rate content streams having the same content but different encoding rates, establishing a connection between the sending host and the receiving host, transmitting data streams with a selected encoded rate to the receiving host, and separating the data streams into data segments of variable length at the sending host as required during transmission.

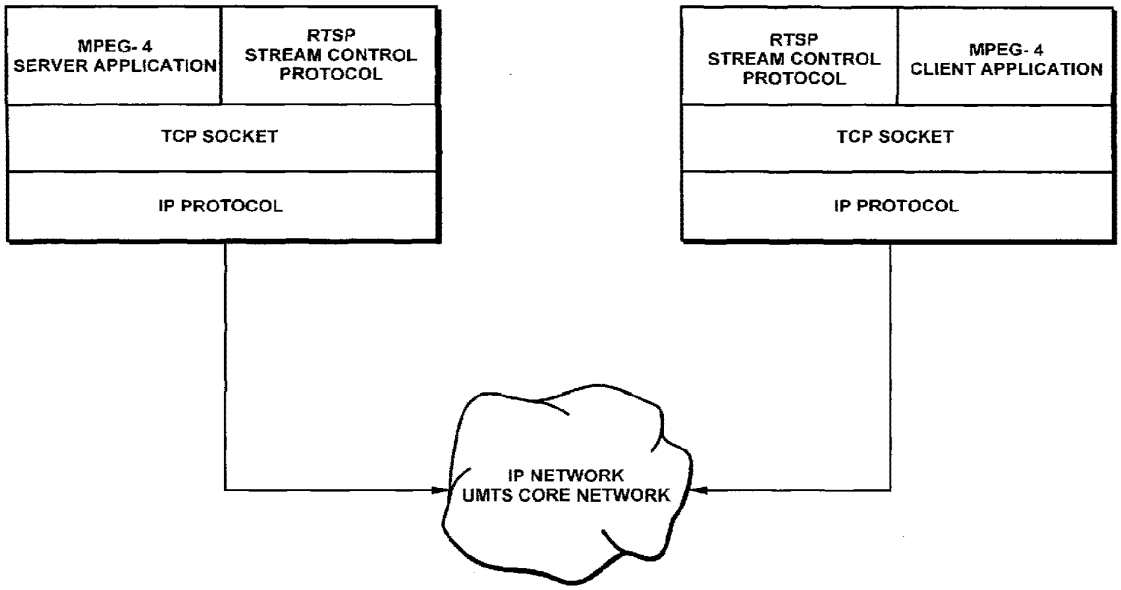


Fig. 1

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Description

[0001] The present invention relates to a method of transmitting data streams between a sending host and a receiving host using a transport protocol such as TCP.

[0002] In network communications between a sending host and a receiving host, the transmission of data packets is mostly done on a best-effort basis. In the communication link, the available bandwidth and the current link conditions vary and hence, the end hosts must be provided with mechanisms to probe and adjust themselves to the current link conditions.

[0003] With the development of 3rd generation networks, so-called streaming applications are gaining importance. Streaming applications are understood as a continuous stream of data, e.g. video or audio data which is typically sensitive to time delays. In order that the user will be able to receive multimedia data streams on a portable receiver, for example a mobile phone, several requirements on the transport mechanism will be imposed in order that the delivered data meets with the resulting time constraints. These constraints are difficult to meet in a best-effort environment, which is subject to bandwidth variations and delays.

[0004] To cope with the problem of bandwidth adaption, it is common praxis to make several data streams with different encoding rates but same content available at the sending host. According to the available bandwidth, it is then switched between the data streams in order to adjust the rate to the available bandwidth. In other words, multi-rate content streams at the sending host are transmitted and switching operations between streams are performed depending on the available bandwidth. The current stream is forwarded to the receiving host in one piece and consequently, for every switching operation, the ongoing connection must be torn down and a new one must be set up. As a result, this operation is inefficient and decreases the data throughput.

[0005] Alternatively, it is possible to transmit only one stream of data to the receiving host and to discard data packets based on priority and time constraints. However, this leads to a loss of data and is therefore not an optimal solution.

[0006] The object subject to the present invention is to minimize the latency of the switching operation and to ensure fast recovery from an incorrect switching decision.

[0007] This object is solved according to the present invention with a method as set forth in claim 1. Preferred embodiments of the method are subject to various dependent claims.

[0008] The method of the present invention supposes the existence of multi-rate content data streams at the sending host. With the method of the present invention, it is possible to quickly switch between data streams that are variably segmented at the application layer as required during transmission. Instead of using data streams of fixed segment length, the data segments given to the socket are made smaller before, during and after the switching. For each content several video streams encoded with different rates are stored at the video server. Under normal sending conditions, i.e. the transmission has reached some equilibrium where the bandwidth is enough and the losses are not dominating, the video content is passed to the sending TCP socket in segments of the same size (irregardless of the stream encoding rate, the segment size is a function of the link, not of the encoding rate). Only when the server is notified (or knows by other means) that a stream switch might be needed, then it reduces the size of these segments.

[0009] Further, with the method of the present invention, it is neither necessary to modify the originally encoded data at the sending host or to modify the transport protocol nor to introduce additional control messages, making the method easy to implement.

[0010] Preferably, the switching is performed between data streams of different rate and the variable segmentation of the data streams is performed around the switching instant. Hence, a quick stream switching from the old to the new data stream can be performed. Further, preferably, the segmentation during, before or after the switching instance is made finer, such that the switching operation is more resilient to an incorrect decision and enables a quicker, further switching operation.

[0011] Advantageously, the step of switching between streams involves a feedback message (e.g. an RTSP command) i.e. communication between hosts when a switching operation is needed and when to make the necessary preparations therefor, for example, to start with finer segmentation.

[0012] It is furthermore of advantage if the feedback message includes at least one of the parameters, which comprise the length of data segment, an identifier of the data to be sent or a stream control command which makes the operation smoother and less susceptible to data losses.

[0013] Preferably, the length of the data segments is gradually increased after a switching instant to reduce interface communication, i.e. between application and TCP socket.

[0014] The present invention will be more fully understood from the following detailed description with reference to the accompanying drawings which show:

Figure 1: the basic architecture of a sending host and a receiving host connected by a communications network in which the method subject to the present invention can be performed,

Figure 2: a block diagram of a server architecture as the sending host in which the method of the present invention is performed, and

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Figure 3: a block diagram of a client architecture.

[0015] Figure 1 illustrates the basic architecture of a communications network for connecting a video server as a sending host to a video client acting as a receiving host. The communications network is, for example, a UMTS core network, an external network, such as the internet or an internal intranet over which the server and the client communicate by means of a transport protocol. As transport protocol TCP is selected as an example, but it is clear to a skilled person that any other transport protocol for transmitting data can be employed.

[0016] In a more general way, it will now be explained how TCP handles the exchange of data between the server and the client.

[0017] First of all, the video server needs to transfer its data to the protocol and tell it to send same to the client. To progressively read and send data, the protocol uses a kind of buffer with added functionalities, a so-called TCP socket. Generally, sockets are unequivocally identified by the IP addresses of the correspondents, the protocols and ports which are used. Once a connection between two sockets is established, the communication can be controlled by use of interface calls, which, for example may comprise "create a socket", "bind a socket to a transport address", "accept" or "close a connection", "send", "receive" or "write" data between the sender and the receiver.

[0018] Wide-spread socket implementations are UNIX BSD 4.2 and Windows Winsock 2.0, where equivalent interface calls are implemented.

[0019] Each interface call has parameters, e.g. for the "send" call, parameters of relevance are the socket descriptor, the identifier of the data to be sent and the length of the data stream. Once a data stream is passed in one call, no single bit of this data stream can be modified. The only way to abort transfer of this data stream is to break down the connection.

[0020] Nevertheless, in order to close the connection, the application must explicitly issue a "close" call. Interface calls can be queued as, for example, in FTP. When asked for a file, the FTP server usually issues two interface calls for this transmission, namely a "send" call indicating the socket, the identifier of the data stream and the length thereof and a "close" call identifying the socket. The two interface calls are put into the queue and when the "send" call is completed, the connection is irreversibly broken down because the "close" call was next in the queue.

[0021] Alternatively, for example, in case of TELNET, the connection is established and the socket is set to wait for incoming data, i.e. commands typed on the keyboard.

[0022] Of course, the application can be configured such that the server only issues a send call and waits for the client to close. However, this is uncommon.

[0023] Additionally, it is assumed that the TCP protocol provides a means for asynchronously signaling certain information about events in the socket. Often in the specification, the information will be an error message. In other cases, there will be information relating to the completion of processing a SEND or RECEIVE or another interface call.

[0024] Referring again to Figure 1, the video server provides, e.g. an MPEG 4 compressed data stream, i. e. a given video content, which is made available to the TCP socket in the form of mono-rate or multi-rate streams. Multi-rate streams are defined for the purpose of this and the following description, as one or several data streams with the same video content at different encoding rates. The MPEG data streams are forwarded to the TCP socket. Subsequently, by means of an IP protocol, data is transmitted to the video client. A stream control protocol, e.g. RTSP, should be used to perform such operating as PLAY, PAUSE or STOP the transmission.

[0025] With reference to Figure 2, which shows the basic architecture of a video server 200, at the MPEG server application 210, video content is made available in a buffer 211 at different coding rates. A switch 212, which receives stream control RTSP commands from RTSP block 220, such as "Play", "Pause", "Tear down" or "Change rate", selects one of the data streams which is forwarded to the TCP socket 230 in form of an MPEG file.

[0026] It is clear to a skilled person that other stream control protocols than RTSP could be used at the server and the client. The stream control protocol typically instructs to perform play, forwarding, rewinding, pause or stop functions. Additionally, if multi-rate content is available, switch to a higher or lower encoding rate can be instructed.

[0027] Once a server has received a request for a file containing a chosen content encoded at a desired rate, the server application forwards each of the segments, in which the file was previously segmented, one after another to the TCP socket by means of consecutive interface calls, e.g. consecutive SEND calls. Unlike in current FTP applications, the connection is not torn down after each data transmission process is completed. The data connection remains open, so that there is no need to build up a new connection every time a segment is transmitted. Following this, the TCP socket forms with these segments packet data units (PDUs) for transmission to the client, as it finds most appropriate

[0028] Upon establishing a connection, the TCP socket selects a segment size for the data streams which the server finds most appropriate for the link under consideration of the channel bandwidth and starts transmitting.

[0029] Initially, the size of the segments is made small before, during and after a switching operation in order to avoid a large waiting time before a further switch operation can be performed in case the previous switch decision was incorrect. Subsequently, the size of the data segments can be increased gradually throughout the connection time.

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[0030] Eventually, when there is a change in the available link bandwidth, the video client shall indicate a possible switch operation by means of, for example, an RTSP message and the server will start doing finer segmentation. Hence, the server switches between data streams of different encoding rates. This is done based on initial information and subsequently controlled by feedback from the client. Alternatively, this could be determined by the server, which would, however, impose processing requirements on the server. Also a combination of control mechanisms at the server and the client is possible. How the server or the client exactly makes the decision to perform a switching operation or indicates a possible anticipated switch is out of the scope of the present invention.

[0031] The basic architecture of a TCP streaming client 300 is illustrated in Figure 3. The client 330 typically consists of a TCP socket 310, an application layer buffer 320 and a buffer manager 330 for the application layer buffer.

[0032] The client 300 processes the data segments of variable length as they come. In response thereto, it sends ACKs and performs flow control in order to prevent an overflow of the TCP socket 310 while extracting the maximum bit rate possible from the link. To do this, the TCP socket indicates to the server, with each ACK, how much data it can receive until the socket is full using a window field in the header of the TCP protocol. If needed, the TCP client signals a zero-window telling the server to enter a "Persist" mode wherein no data is sent until the client allows to do so while the connection is maintained. The Persist mode and the signaling of a window field are standard functionalities of the TCP protocol. When the TCP circuit has capacity for more data, it signals this to the server. Streaming control commands are signalled to the server by means of RTSP commands.

[0033] The application layer buffer 320, also called "play-out buffer" receives data from the socket and transmits same to the MPEG client application 340. The manager 330 for the application layer buffer 320 receives a frame request from the MPEG client application and issues a socket request upon considering the state of the application layer buffer. The buffer manager 320 therefore insures that the bit rate with which the TCP socket 310 can deliver the new data to the application layer buffer 320 matches the bit rate at which the application layer buffer is emptied to the MPEG client application 340. The exact control mechanism of the buffer manager is out of the scope of the present invention.

[0034] Finally, from the MPEG client application, the data is transferred to a display 350 for visualization for the user.

Claims

1. A method of transmitting data streams between a sending host and a receiving host using a transport protocol comprising the steps of:

   making available data streams at the sending host in form of mono-rate or multi-rate content streams having same content but different encoding rates,

   establishing a connection between the sending host and the receiving host for the duration of transmission,

   transmitting data streams of the same content with a selected encoding rate to the receiving host, and

   separating the data streams in data segments of variable length at the sending host as required during the established connection.

2. The method according to claim 1, further comprising the steps of switching between data streams of different rate and performing the variable segmentation of the data streams around the switching instant.

3. The method according to claim 1 or 2, wherein the data streams are finer segmented during, before or after the switching instant.

4. The method according to claim 2, wherein the step of switching between streams involves a feedback message.

5. The method according to claim 4, wherein the feedback message includes signalling at least one of the parameters which comprise data segment length, an identifier of the data to be sent or a stream control command.

6. The method according to one of claims 1-5, wherein the receiving host communicates to the sending host when a stream switching is needed.

7. The method according to one of claims 1-6, wherein the sending host determines the timing of the switching instant dependent on the available bandwidth of the communication link.

8. The method according to one of claims 1-7, wherein the length of the data segments is gradually increased after a switching instant.

9. The method according to one of claims 1-8, wherein the received data streams at the receiving host are temporarily stored in an internal buffer.

10. The method according to one of claims 1-9, wherein the receiving host issues stream control commands

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to the sending host depending on the state of the internal buffer.

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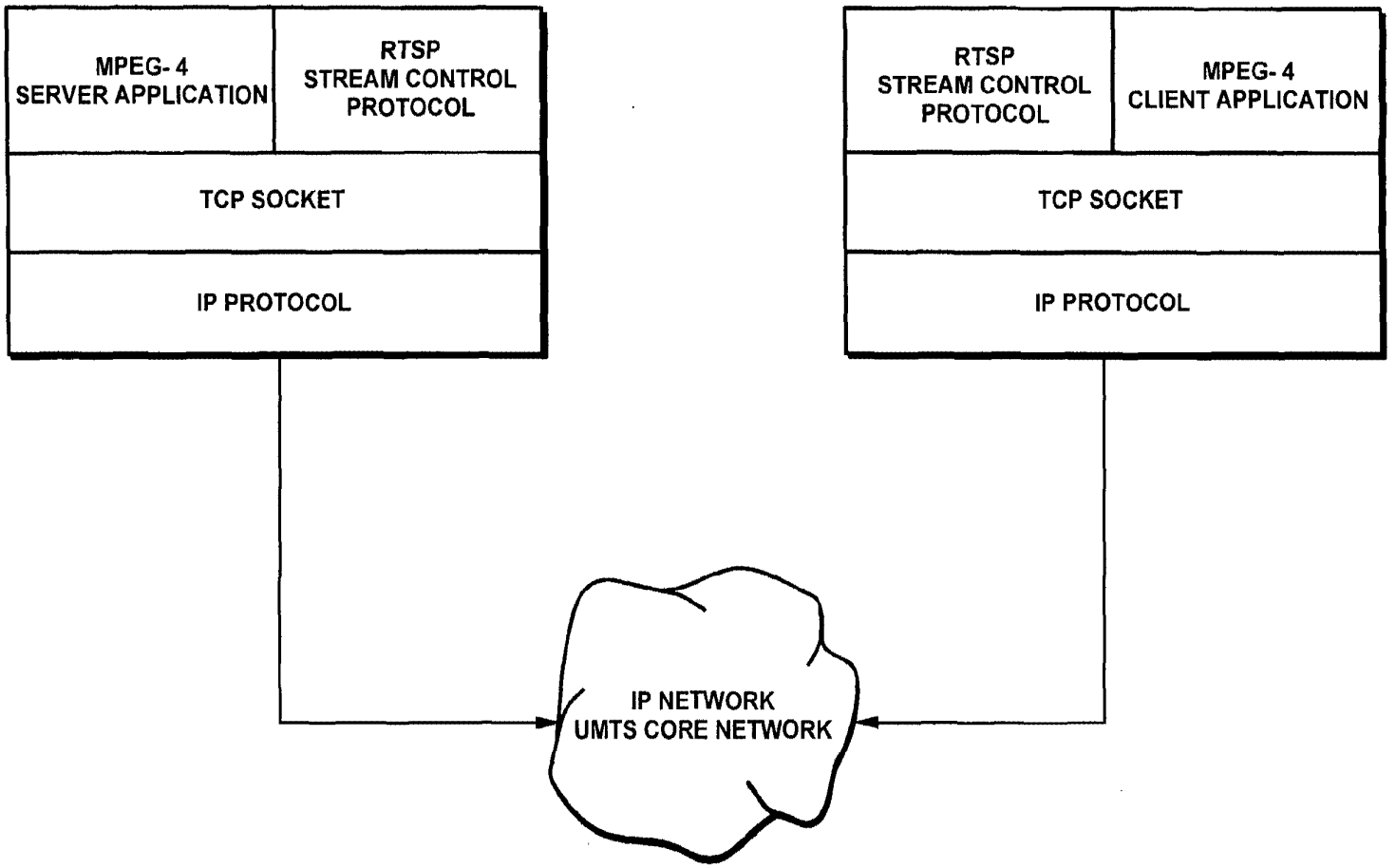


Fig. 1

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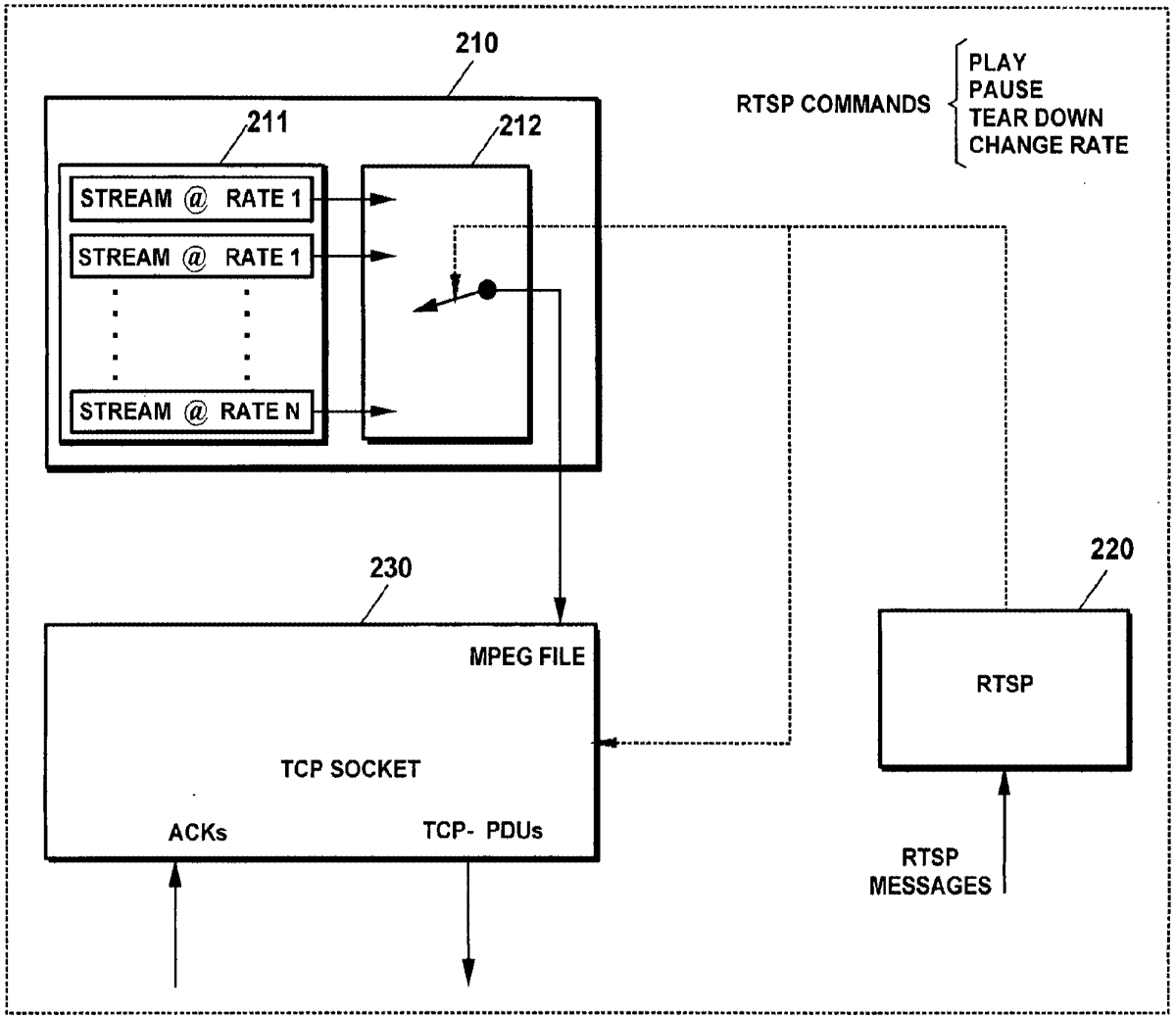


Fig. 2

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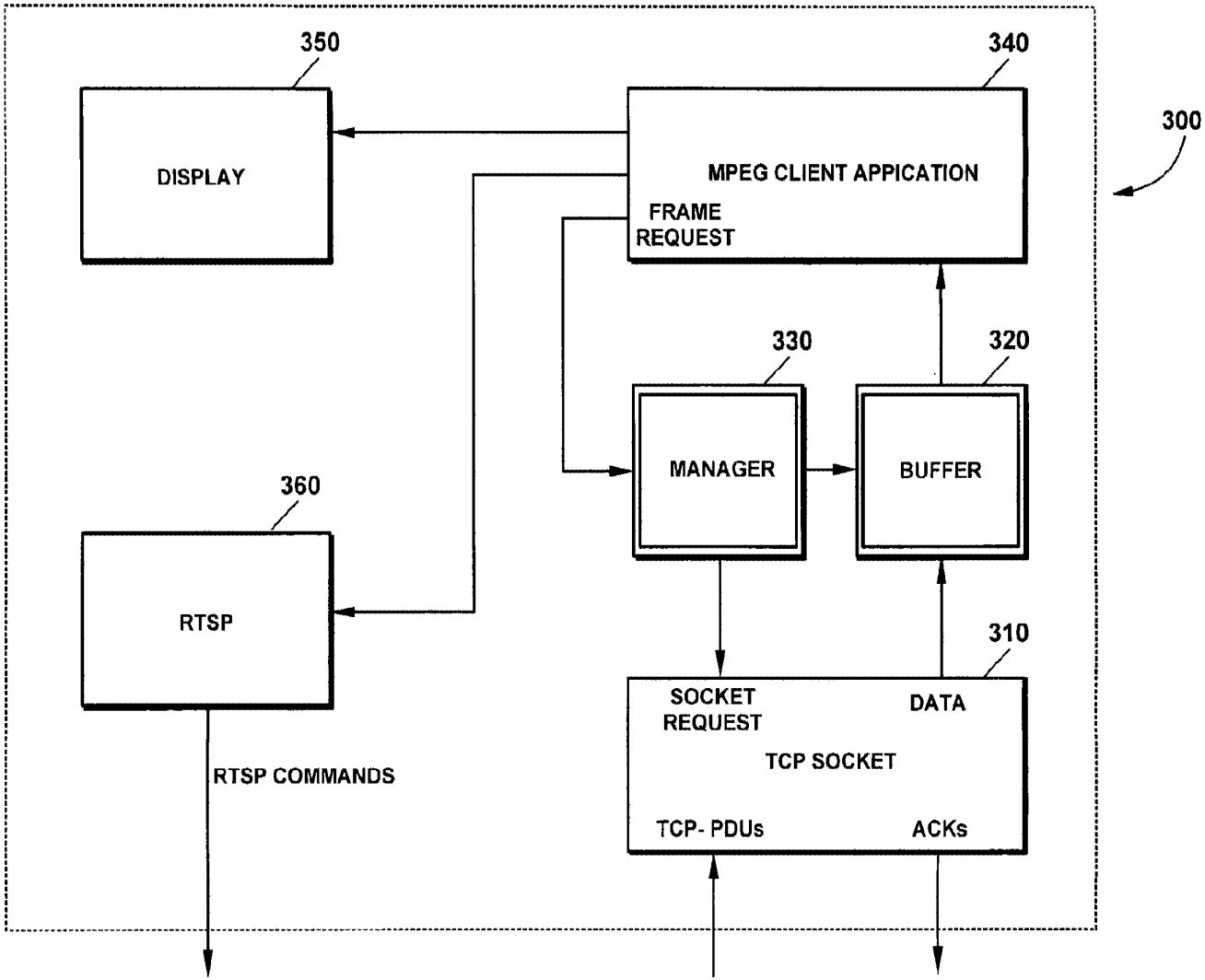


Fig. 3

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European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 02 01 9052

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
Y	CONKLIN G J ET AL: "VIDEO CODING FOR STREAMING MEDIA DELIVERY ON THE INTERNET" IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS FOR VIDEO TECHNOLOGY, IEEE INC. NEW YORK, US, vol. 11, no. 3, March 2001 (2001-03), pages 269-281, XP001093477 ISSN: 1051-8215 * page 271, left-hand column, line 35 - line 44; figures 1,2 * * page 270, left-hand column, line 11 - line 20 * ---	1-10	H04L29/06 H04L29/08
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X	WO 02 054284 A (LEISTAD GEIRR I ;DANKWORTH HARALD (NO); FAST SEARCH & TRANSFER ASA) 11 July 2002 (2002-07-11) * page 2, line 31 - page 3, line 7 * * page 4, line 6 - page 5, line 6; figure 1 * * page 9, line 18 - page 10, line 15 * * page 11, line 3 - line 28; figure 3 * --- -/--	1	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)
H04L

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	7 January 2003	Michael, T

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
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European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 02 01 9052

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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A	JONGWON KIM ET AL: "TCP-friendly Internet video streaming employing variable frame rate encoding and interpolation" IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS FOR VIDEO TECHNOLOGY, vol. 10, no. 7, October 2000 (2000-10), pages 1164-1177, XP002226167 ISSN: 1051-8215 * page 1164, right-hand column, line 25 - line 40; figure 1 * ---	7	TECHNICAL FIELDS SEARCHED (Int.Cl.7)
A	WO 02 052859 A (DURRANT SIMON ;LAKE JULIAN (GB); MULROY PAT (GB); PA CONSULTING SE) 4 July 2002 (2002-07-04) * page 3, line 12 - line 30 * -----	7	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	7 January 2003	Michael, T

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 02 01 9052

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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07-01-2003

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		EP 0786885 A2	30-07-1997
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		WO 02054284 A1	11-07-2002
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EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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(19) Europäisches Patentamt
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(11) EP 1 202 487 A2

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(21) Application number: **01309276.2**

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29.06.2001 JP 2001200156

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(54) Data transmission apparatus and method

(57) A data transmission apparatus comprises a network condition determination device for determining a transmission condition of the transmission channel in the transmitter (103) based on at least Jitter information or a packet loss rate obtained from a receiver (104), and a video encoder (102) including means for changing at least one of a bit rate of transmission data and a error resilience level according to the transmission condition.

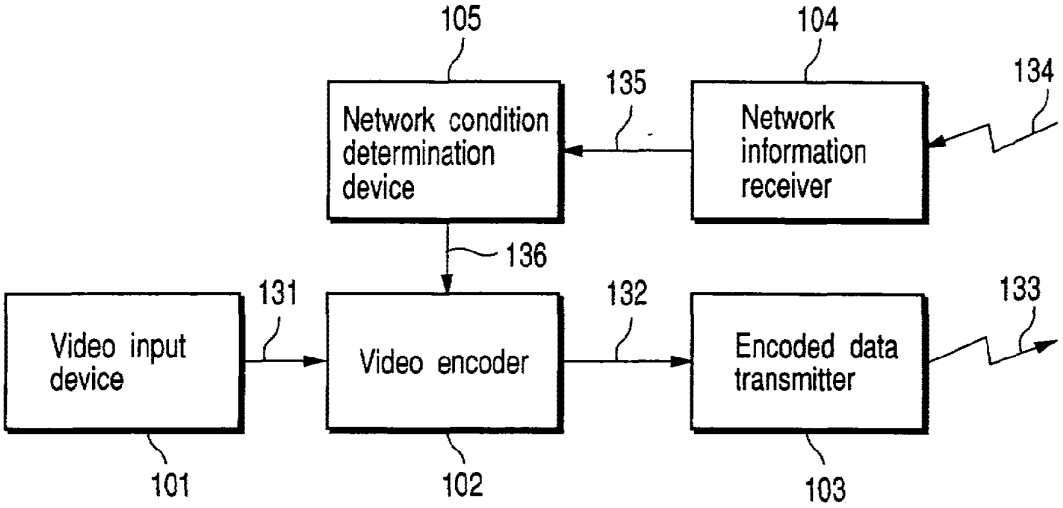


FIG. 1

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Description

[0001] The present invention relates to a data transmission method for transmitting encoded moving/still picture by using a wired communication network such as ISDN (Integrated Services Digital Network) or a wireless communication network such as PHS (Personal handy-phone System) or satellite communication and a data transmission apparatus to which such method is applied.

[0002] In recent years, with progress of digital encoding technology of a variety of information such as image and a broadband network technology, the development of applications using these technologies becomes active, and a system of transmitting compression-encoded image by utilizing a communication network is developed.

[0003] For example, an input video signal is encoded at a video encoder, the obtained encoded data is provided to an encoded data transmitter, and transmission data is transmitted to a transmission channel. In this way, a video is encoded and transmitted. In recent years, with the spread of Internet/Intranet, there has been increased an application or system of transmitting/receiving a packet of data. Providing data as a packet is very effective means for efficiently sharing a bandwidth of a communication channel by a plurality of users.

[0004] In the meantime, as a protocol for transmitting/receiving packet data via Internet/Intranet, there exists TCP/IP (Transmission Control Protocol/Internet Protocol) or UDP/IP (User Datagram Protocol/Internet Protocol) and the like.

[0005] Among them, TCP/IP is an Internet standard protocol. This protocol is applied as the world's best known protocol to Intranet or LAN as well as Internet. TCP works in a transport layer that is a fourth layer of an OSI basic reference model, and IP works in a network layer that is a third layer.

[0006] In addition, UDP/IP is one of the TCP/IP suite transport layer protocols. TCP is a connection type protocol. UDP is a disconnection type protocol. As with TCP, a host application is identified by using a port number. This protocol is often used to carry short data for monitor control of a network or real time oriented data such as audio data or video data.

[0007] TCP/IP incorporates a frame such as retransmission. Thus, this protocol is strong against errors or the like. Even if a large amount of time is required, this protocol is effective to download type applications if an attempt is made to validly receive data. However, this protocol is not powerful for applications requiring real time properties.

[0008] In contrast, although UDP/IP does not have a retransmission frame, a delay associated with retransmission does not occur. Thus, this protocol is very effective to applications requiring real time processing.

[0009] Transmission of moving picture is exemplified as a typical example of application requiring real time processing. However, in the case of general video communication, video data has a very large amount of data, and overflows a network bandwidth in most cases. In this case, a technique for encoding a video data signal, and transmitting a reduced amount of data is used. Techniques such as motion compensation, discrete cosine transform (DCT), sub-band encoding, pyramid encoding, and variable-length encoding or a combination of these techniques are developed as compression-encoding of a video signal.

[0010] As an international standard system for moving picture encoding, there are ISO MPEG-1, MPEG-2, ITU-T H. 261, H. 262, and H. 263. In addition, as an international standard system for multiplying an encoded data stream having a speech/audio signal compressed or other data, there are an ISO MPEG system, ITU-T H. 221, and H. 223.

[0011] Internet or the like is encompassed via an infinite number of networks. Usually, no one knows which network is used or what state is. In addition, an amount of data flowing a network changes from time to time. Thus, a system of judging what amount of data can be communicated in a real time is required.

[0012] Therefore, with further advancement from real time applications utilizing UDP/IP, there have been increased in number applications using a packet format called RTP (Real-time Transport Protocol) for adding and transmitting time information or the like to a packet.

[0013] This RTP is a protocol for transferring audio data signal or video data signal ruled in RFC 1889 in real time. Usually, data is carried on UDP (User Datagram Protocol). This protocol is assumed to be applied to a multimedia system such as video conference, and data can be exchanged in a real time interactive scheme. However, the protocol has no sound quality or picture quality assurance function. Sequential number or time stamp data is assigned into an RTP header, thereby supporting a read time operation.

[0014] RFC is an abbreviation of Request for Comments, and denotes a document such as technical proposal or comments disclosed by TETF (Internet Engineering Task Force). Many de-fact standards such as a variety of protocols of TCP/IP suite are described in RFC.

[0015] By utilizing this RTP, time information and a packet number are added to a packet, so that a receiver can display a voice or image by using correct time information, can determine a packet or the like whose order is replaced in a network, and can detect that a packet is lost by referring to a packet number.

[0016] Moreover, the RTP provides with a system (RTCP) for notifying network state information such as jitter or packet loss rate from a transmitter to a receiver.

[0017] However, how this RTCP information is utilized depends on applications, and is not determined in standards.

[0018] In addition, in the case of an image, a bandwidth corresponding to video transmission cannot be al-

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located in a network bandwidth, thus making it necessary to compress and deliver a video signal in an encoding system such as MPEG, as described previously. Although this encoding system is effective in a decreased amount of data, the system becomes very fragile to a packet loss or error entry by supplying data to unstable Internet. This is because a moving picture encoding system transmits only a difference between a current frame and a previous frame. Thus, partial data missing causes a very serious problem. In the case of using the UDP or RTP, data retransmission is not basically carried out, thus making it necessary to counteract this problem.

[0019] There generally exist two modes in picture encoding, that is, one is an inter-frame encoding mode for transmitting a difference between the current frame and the previous frame and an intra-frame encoding mode for carrying out encoding in one frame. In general, intra-frame encoded pictures are provided at a proper timing, and inter-frame encoded pictures are provided between them. An interval between the frames encoded in an intra-frame encoding mode is called a GOP (Group of Picture) interval.

[0020] When an encoded picture is missing during transmission to the decoder, the decoded picture corresponding to the missing encoded picture is destroyed. Thereafter, the intra-encoded pictures following the missing encoded picture are decoded based on the destroyed picture. Thus, all the subsequent decoding pictures are affected by the destroyed picture, and decoding cannot be carried out correctly. Therefore, an intra-frame encoded picture is inserted in the way of a stream of frames to cut off a propagation of missing error and recover adequate decoding.

[0021] In a conventional technology, it can determine that errors occur in a network. However, how to utilize the determination result has been unknown. Also, a system for notifying the network information to the transmitter in an unique format is conceived. However, the system is based on the specification of associated applications and lacks a general-purpose use. The system receives transmission data using an information receiver, and controls a video encoder within a range of the information received from the network via a transmission channel.

[0022] A conventional network condition determination is conceived on assumption of network congestion. However, since Internet is popularized in mobile environment, it is required to consider an error or the like in wireless environment. Current technique does not assume countermeasures against such error.

[0023] Further, in the case of dealing with the error, a case in which a network condition changes, and an error rate is not constant is not considered. If a short GOP interval is set in order to counteract a case in which errors frequently occur, the intra-frame encoding increases resulting in impairing the encoding efficiency. When errors occur frequently qualitatively, it may be required to establish such state in which such errors occur frequently. However, in the case of a network in which an error hardly occurs in a normal state, and an error occurs only at one moment, this setting is very wasteful. Conversely, when a long GOP interval is set, it is troublesome that a great influence occurs when an error occurs.

[0024] Thus, a real time transmission using RTP is noted. As described above, by utilizing the RTP that is a protocol for transferring audio data signal or video data signal in real time, time information and a packet number are added to a packet, whereby the receiver can display a voice or image by using correct time information, can determine a packet or the like whose order is replaced in a network, or can detect that a packet is lost by referring to a packet number.

[0025] Moreover, at the RTP, there is provided a system (RTCP) for notifying network state information such as jitter or packet loss rate from the transmitter or receiver.

[0026] It is an object of the present invention to provide a data transmission apparatus and method capable of adjusting a transmission rate by using the RTP characteristics in accordance with a transmission state of a transmission channel based on notification of network state information such as jitter or packet loss rate, obtained from the receiver in the transmitter or capable of carrying out controls such as changing error resilience, thereby making it possible to efficiently transmit data to the maximum, and fully utilize transmission that requires real time properties.

[0027] According to an aspect of the invention, there is provided a data transmission apparatus that transmits transmission data from a transmitter to a receiver via a transmission channel, comprising: an estimation device configured to estimate a transmission condition of the transmission channel in the transmitter based on at least Jitter information or a packet loss rate obtained from the receiver; and a controller configured to change at least one of a bit rate of transmission data and a error resilience level according to the estimated transmission condition.

[0028] According to another aspect of the invention, there is provided a data transmission method comprising: estimating a transmission condition of the transmission channel in the transmitter based on at least Jitter information or a packet loss rate obtained from the receiver; and changing at least one of a bit rate of transmission data and an error resilience level according to the estimated transmission condition.

[0029] According to another aspect of the invention, there is provided a data transmission program stored on a computer readable medium, comprising: instruction means for instructing a computer to estimate a transmission condition of the transmission channel in the transmitter based on at least Jitter information or a packet loss rate obtained from the receiver; and instruction means for instructing the computer to change at least

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one of a bit rate of transmission data and a error resilience level according to the estimated transmission condition.

[0030] This summary of the invention does not necessarily describe all necessary features so that the invention may also be a sub-combination of these described features.

[0031] The invention can be more fully understood from the following detailed description when taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a view showing a basic configuration of a data transmission apparatus according to a first embodiment of the present invention;
FIG. 2 is a view showing another configuration in the present embodiment;
FIG. 3 is a view showing a configuration of a network condition determination device in the present embodiment;
FIG. 4 is a view showing a configuration of a video encoder in the present embodiment;
FIG. 5 is a view showing a configuration of an encoded parameter determining device in the present embodiment;
FIG. 6 is a view showing a basic configuration of a data transmission apparatus in a second embodiment of the present invention;
FIG. 7 is a view showing a configuration of an encoded data switch device in the present embodiment;
FIG. 8 is a view illustrating a timing of encoded data switching at an encoded data switch device in the present embodiment;
FIG. 9 is a view illustrating a timing of switching encoded data with its different frame interval at the encoded data switch device in the present embodiment;
FIG. 10 is a flow chart showing a basic example of the network condition determination method at the network condition determination device in the first embodiment of the present invention;
FIG. 11 is a flow chart showing a basic example when a delay is forced to occur by using the network condition determination method at the network condition determination device in the first embodiment of the present invention;
FIG. 12 is a flow chart showing a basic example considering a time direction change with the network condition determination method at the network condition determination device in the present embodiment;
FIG. 13 is a view showing an exemplary configuration according to a third embodiment of the present invention;
FIG. 14 is a flow chart showing an example of a GOP interval calculation method at a GOP interval calculator in the present embodiment;
FIG. 15 is a flow chart showing another example of a GOP interval calculation method at a GOP interval calculator in the present embodiment; and
FIG. 16 is a flow chart showing still another example of a GOP interval calculation method at a GOP interval calculator in the present embodiment.

[0032] Hereinafter, embodiments of the present invention will be described with reference to the accompanying drawings.

[0033] The present invention utilizes RTP or RTCP that is a protocol for transferring audio data signal or video data signal in real time. The transmitter performs controls such as adjusting a transmission rate or changing error resilience in accordance with a transmission state of a transmission channel based on notification of network state information acquired from the receiver such as jitter (Jitter information) or packet loss rate. In this manner, data transmission can be carried out efficiently to the maximum. Hereinafter, embodiments of the present invention will be described in detail.

(First Embodiment)

[0034] FIG. 1 shows a basic configuration of an image transmission apparatus according to a first embodiment of the present invention. In FIG. 1, a video signal 131 input from an image input device 101 is processed to be encoded. That is, an encoded data transmitter 103 processes encoded data 132 that has been encoded by a video decoder 102 in the form which conforms to a network, and transmits the encoded data to a receiver. A network information receiver 104 receives network information 134 delivered from the receiver, and outputs the received information to a network condition determination device 105. This network condition determination device 105 has a function that determines a network condition from network information 135 output from the network information receiver 104, and notifies the result as network condition information 136 to the video encoder 102.

[0035] The video encoder 102 encodes the video signal 131 using the network condition information 136. This encoding is carried out as follows. That is, in the case of RTP or RTCP, a packet loss rate or Jitter information is provided to the network condition determination device 105. The network condition determination device 105 determines that, if a packet loss rate is not "0" or if a delay time is longer than a predetermined value, any load is applied to a network, and a presumed amount of data cannot be supplied. Then, the network condition determination device 105 is configured so as to carry out processing so as to issue an instruction (network condition information 136) for lowering a bit rate to the video encoder 102, and to lowly set a target bit rate in encoding.

[0036] According to the thus configured apparatus, when the video signal 131 is inputted from the image input device 101, the inputted video signal 131 is encod-

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ed by the video encoder 102. Encoded data 132 encoded by the video encoder 102 is inputted to the encoded data transmitter 103.

[0037] The encoded data transmitter 103 processes the encoded data in the form suitable to a network, and receives the processed data to a receiver. The network information receiver 104 receives the network information 134 delivered from the receiver, and outputs the received information to the network condition determination device 105.

[0038] The network condition determination device 105 determines a network condition from the network information 135 outputted from a network information receiver, and notifies the result as the network condition information 136 to the video encoder 102.

[0039] The video encoder 102 encodes the video signal 131 using the thus notified network condition information 136.

[0040] FIG. 10 shows a very simple example of a method for determining a network condition at the network condition determination device 105 by way of showing a flow chart.

[0041] According to this flow chart, at the step S1001, a packet loss rate of network information is checked to see if the rate is "0" or not. As the result of this check, if the packet loss is not "0", an effective bit rate is calculated from the packet loss rate in accordance with the step S1002. This bit rate can be calculated by formula (1) shown below.

$$b' = b \times (1 - r) \quad (1)$$

where "b" denotes a current bit rate, b' denotes a new bit rate, and "r" denotes a packet loss rate.

[0042] Next, at the step S1003, a parameter (encoding parameter) obtained at the step S1002 is notified to the video encoder 102. Here, the above parameter is used to determine a rate control or error resilience level for encode processing at the image encoder 102. This parameter is also used for adjustments such as adjusting and controlling the encode processing speed of the input image signal 131 to this parameter, thereby changing a bit rate, a frame interval, or an error resilience level.

[0043] On the other hand, at the step S1001, when the packet loss rate is "0", no parameter change occurs at the step S1004. This determination method is provided as a mere example. It is possible to employ any other method for obtaining a bit rate based on a case in which the criterion of the step S1001 is determined by thresholds without being set to "0" or others or based on a formula other than the above formula (1).

[0044] Therefore, according to the first embodiment, even when a transmission network bandwidth is unknown or when the bandwidth changes halfway, it is possible to reset a parameter or the like based on the receiver's network information, and then, encode and transmit an image in accordance with the parameter suitable to a current network. In this manner, even in the case of a network congestion, although a bit rate is automatically lowered, and an image quality is lowered, it is possible to communicate an image without an occurrence of a phenomenon that an image is destroyed due to such packet loss. This method is very effective in image transmission in real time.

[0045] The first embodiment can be carried out by modifying it as follows. For example, as shown in FIG. 11, a method other than that shown in FIG. 10 is employed as a method for determining a network condition at the network condition determination device 105. That is, in the flow chart shown in FIG. 10, a parameter is set at only a packet loss rate. In contrast, in the method shown in FIG. 11, even when no packet loss occurs at the step S1104, a delay quantity is checked. As a result of this check, if a delay occurs in excess of a predetermined value, it is determined that a network is congested. When it is determined that a network is congested, a bit rate is calculated, and a new parameter is set by using formula (2) below, for example, at the step S1105.

$$b' = b \times \{(TN-TS)+(d-dth)\}/(TN-TS) \quad (2)$$

where "b" denotes a delay time, b' denotes a new bit rate, TN denotes a current time, TS denotes a start time, "d" denotes a delay time, and "dth" denotes delay time thresholds.

[0046] FIG. 2 shows an example when the network condition determination device 105 is provided with a function for generating the network condition information 136 so as to provide the information to the image encoder 102 by extending the configuration shown in FIG. 1.

[0047] According to a configuration shown in FIG. 2, the network condition determination device 105 is provided with a function for acquiring a current parameter at the current image encoder 102 and a function for generating the network condition information 136 on what parameter should be set next from the thus acquired current parameter and network information 135, thereby providing the parameter to the image encoder 102.

[0048] In the case of this construction, the network condition determination device 105 can recognize a state of a video parameter, i.e., a state of the encode processing currently done at the video encoder 102, thus making it possible for the network condition determination device to calculate and grasp a bit rate or the like. This construction is advantageous in the case of determining a network condition by comparing the network information 135 with parameter information 137. Thus, a system is realized which is capable of changing a parameter so as to set an optimal bit rate in accordance with the network condition, and providing the parameter to the video encoder 102, thereby adjusting the encode processing.

[0049] In this way, according to the present invention,

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transmission is adjusted in accordance with a transmission state of a transmission channel or error resilience is changed. The transmission state is adjusted by changing a bit rate or changing a frame interval. With respect to a change in quality of a transmission channel, the error resilience is changed according to the transmission state of the transmission channel (for example, the error resilience is changed by changing an interval of an MPEG4 synchronous signal). Therefore, data transmission can be carried out efficiently to the maximum, thereby enabling data transmission that makes it possible to fully utilize transmission requiring real time processing.

[0050] FIG. 3 shows a configuration when the configuration shown in FIG. 2 is further developed. This network condition determination device 105 comprises a network information storage device 301 that stores past network information and an encoded parameter information storage device 302 that stores encoded parameter information supplied to the current video encoder 102. A network condition determination device 303 recognizes the past network information and the current encoded parameter from these elements, decides an elapse of time in network condition from these elements to determine an optimal parameter assigned to the video encoder 102, and provides the parameter to the video encoder 102.

[0051] With this construction, it is possible to determine a network condition more accurately by referring to an elapse of time relevant to network information. FIG. 12 shows a flow chart of a network condition determination method in the case of using this system. Processing at the network condition determination device 303 will be described in accordance with this flow chart. First, the network condition determination device 303 determines whether or not packet loss is "0" at the step S1201. As a result of this determination, when the packet loss is present, it is determined by the step S1202 whether or not the past packet loss occurs. As a result, when the past packet loss occurs, the loss rate is compared with the current rate. If the current packet loss rate is higher than the past packet loss rate, it can be determined that the past correction has been invalid.

[0052] It is understood from this determination that the bandwidth overflow of transmission data such as network congestion is not troublesome, but a possibility that a noise or the like occurs over a channel resulting in destroying is high. Therefore, the network condition determination device 303 does not change a bit rate at the step S1204, and carries out parameter setting to ensure reliable error correction, and notifies the fact to the video encoder 102 at the step S1205.

[0053] If the current packet loss rate is lower than the past packet loss rate at the step S1203, the network condition determination device 303 determines that the past change works efficiently, and re-calculates a valid bit rate from the packet loss rate at the step S1206. When the past packet loss does not occur at the step S1202, the last loss is determined as a channel noise, and processing goes to the step S1204.

[0054] On the other hand, when no packet loss occurs at the step S1201, the network condition determination device 303 checks a delay quantity at the step S1207. As a result, when the delay quantity exceeds thresholds "Th", a valid bit rate is calculated from the delay quantity at the step S1208, and the calculation result is notified to the video encoder 102 at the step S1205.

[0055] Lastly, when the delay quantity does not exceeds the thresholds "Th", the network condition determination device 303 determines that successful communication is established, and does not change a parameter at the step S1209.

[0056] By causing the network condition determination device 303 to carry out such processing, the network condition determination device 105 can have a function capable of determining whether a packet loss occurs on a transmission channel due to network congestion or whether a noise is generated, and the loss occurs due to the impairment of a channel state such as radio equipment.

[0057] This function is provided as a mere example. For example, when the past packet loss does not occur at the step S1202, a control for lowering a bit rate may be made by determining network congestion instead of determination of noise. If the current packet loss rate is improved more remarkably than the past packet loss rate at the step S1203, similar parameter change may be made after checking how the past change has been made. In this way, in this system, a variety of determination systems can be set according to a network.

[0058] In the foregoing, although there has been shown an example in which the video encoder 102 carries out encode processing based on encoded parameters determined and assigned at the network condition determination device 105, a configuration for the video encoder 102 to determine a parameter can be provided without being limited to the network condition determination device 105. An example is shown in FIG. 4.

[0059] FIG. 4 is a block diagram depicting an inclusive configuration when the video encoder 102 determines an encoded parameter. In the case of this example, the video encoder 102 comprises an encoded parameter determination device 401 and a signal processor 402.

[0060] In the case of this configuration, the network condition determination device 105 is configured to output the network condition information 136 from the network condition determination device 303, and then, provide the information to the video encoder 102.

[0061] In such a configuration, the network condition determination device 105 provides the network condition information 136 delivered from the network condition determination device 303 to the video encoder 102. Then, the video encoder 102 first inputs the network condition information 136 to an encoded parameter determination device 401. Then, the encoded parameter determination device 401 recognizes a network condi-

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tion from this network condition information 136, and generates an encoded parameter 431 in the form suitable to the network condition.

[0062] The thus generated encoded parameter 431 is inputted to a signal processor 402. Then, this signal processor 402 encodes the video signal 131 inputted from the video input device 101 by using this encoded parameter 431.

[0063] Encoding information 432 such as the number of encoded bits after encoding is inputted to the encoded parameter determination device 401, and is used for the next encoded parameter determination. Encoded data 132 encoded at the signal processor 402 is output to the encoded data transmitter 103.

[0064] FIG. 5 is a block diagram depicting a configuration including a intra-frame encoding determination device 501 that forcibly sets intra-frame encoding at the encoded parameter determination device 401 shown in FIG. 4. As shown in the figure, the encoded parameter determination device 401 comprises an intra-frame encoding/determination device 501 and an encoded parameter determination device 502.

[0065] In the case of this configuration, the network condition information 136 outputted from the network condition determination device 105 is input to the encoded parameter determination device 502 possessed by the encoded parameter determination device 401. Then, encoded parameter information 531 corresponding to the network condition information 136 is output from the encoded parameter determination device 502.

[0066] The encoded parameter information 531 is input to the intra-frame encoding determination device 501, and it is determined whether inter-frame encoding is carried out as is or intra-frame encoding is forcibly carried out. When it is determined as intra-frame encoding, the encoding parameter information 531 is updated so as to carry out intra-frame encoding, and is output as the encoded,parameter information 431 to the signal processor 402 of the video encoder 102.

[0067] By doing this, even if the past data is not transmitted correctly to a receiver, when the data can be received correctly after parameter change, a correct image can be reproduced.

[0068] It is possible to configure a video encoder capable of determining a network condition, which has functions of the video encoder 102 and network condition determination device 105, thereby making it possible to provide the previously described function in one block.

[0069] The encoded parameter determination device 401 or network condition determination device 105 makes determination concerning the next encoded parameter setting. However, if a picture quality is changed suddenly due to temporary instability of network, an unclear picture may be produced. In order to suppress such a phenomenon, it is possible to incorporate a mechanism in which a change in encoded parameter is suppressed within its predetermined range. In the above described circumstance, this mechanism functions efficiently.

[0070] Although a bit rate or an error resilience parameter may be set as its calculated value, it is possible to employ a method of predetermining some patterns, and then, selecting the closest pattern from among them. Further, instead of the closest pattern, it is possible to make a selection of the closest bit rate which is lower than the calculated bit rate. This makes it possible to prevent the generation of a video image with its unexpected image quality due to a combination of a variety of parameters, and makes it possible to prepare a combination of encoded parameters that have been tested to some extent.

[0071] In the foregoing example, when the packet loss rate is not "0" or when a delay exceeds the thresholds, there has been made a control such that parameters such as bit rate or error resilience are changed, and the changed is reset to that suitable to the current state.

[0072] However, after recovery of a network condition, when no packet loss occurs or when a small delay occurs, it is possible to make a control for increasing a bit rate or decreasing an error resilience parameter.

[0073] The foregoing example will be described below according to a second embodiment.

(Second Embodiment)

[0074] FIG. 6 is a view showing a basic configuration of an image transmission apparatus according to the second embodiment of the present invention. The image transmission apparatus shown in FIG. 6 comprises a plurality of media 601, an encoded data switch device 602, an encoded data selector 603, an encoded data transmitter 103, a network information receiver 104, and a network condition determination device 105.

[0075] The storage media 601 are used to store encoded data 631 on contents that have been encoded in advance. The storage media 601 each store encoded data on the same contents encoded by different encoded parameters, respectively.

[0076] The encoded data switch device 602 selects one of a plurality of storage media 601, and provides encoding data 631 stored in the thus selected storage medium 601 to the encoded data transmitter 103. A selection of the storage media is carried out in accordance with switch information 632 from the encoded data selector 603.

[0077] The network information receiver 104 has a function that receives network information 134 such as packet loss rate or Jitter information delivered from a receiver or a network, and provides the received information as network information 135 to the network condition determination device 105.

[0078] The network condition determination device 105 determines a network condition from the input network information 135, and outputs the result as network condition information 136 to the encoded data selector

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603. The encoded data selector 603 has a function for estimating, from this network condition information 136, which of the encoded data on encoding parameters is optimal to the current network, and then, outputting to the encoded data switch device 602 the switch information 632 used for switching in order to select encoded data caused by the estimated optimal encoding parameter as an output.

[0079] The encoded data switch device 602 selects one item of encoded data from among the input encoded data 631, and outputs encoded data 132.

[0080] With such a configuration, the encoded data 631 encoded in advance and store in the storage medium 601 or the like is input to an encoding data switch device 602 when the data is reproduced from the storage medium 601. That is, respective encoded data encoded by the differential encoding parameters are maintained in a plurality of storage media 601. As a result of reproducing these items of data, the encoded data encoded by the different encoding parameters, respectively, is inputted. The encoded data switch device 602 selects one from among these items of data, and outputs it to the encoded data transmitter 103.

[0081] This selection is carried out in accordance with switch information 632 from the encoded data selector 603.

[0082] On the other hand, network information 134 such as packet loss rate or Jitter information from a receiver is received at the network information receiver 104, and then, the received information is delivered to the network condition determination device 105. The network condition determination device 105 determines a network condition from the inputted network information 135, and outputs the result as network condition information 136 to an encoded data selector 603.

[0083] The encoded data selector 603 estimates, from the network condition information 136, which of the encoded data of the encoding parameters is optimal to the current network, and outputs the switch information 632 to the encoded data switch device 602.

[0084] The encoded data switch device 602 selects one item of the encoded data from among the input encoded data 631, and outputs encoded data 132.

[0085] The present embodiment will be described by way of a specific example.

[0086] Now, assume that there exist five storage media 601a to 601e each having stored therein five items of encoded data encoded at 384 kbps, 128 kbps, 64 kbps, 32 kbps, and 16 kbps.

[0087] That is, for example, a storage medium having stored therein encoded data on contents encoded at 384 kbps is defined as a storage medium 601a; a storage medium having stored therein encoded data on contents encoded at 128 kbps is defined as a storage medium 601b; a storage medium having stored therein encoded data on contents encoded at 64 kbps is defined as a storage medium 601c; a storage medium having stored therein encoded data on contents encoded at 32 kbps is defined as a storage medium 601d; and a storage medium having stored therein encoded data on contents encoded at 16 kbps is defined as a storage medium 601e.

[0088] In the case of using a transmission channel having its quality capable of being transmitted at 384 kbps, first, reproduced encoded data is selected by the storage medium 601a that is a storage medium having stored therein encoded data on contents encoded at 384 kbps; transmission is started at 384 kbps, and reception of network information from the receiver starts at the same time.

[0089] Although network information is received at a predetermined interval, if a problem occurs with a network based on the received information, a valid bit rate is calculated at a stage at which a packet loss or delay occurs. The encoded data selector 603 selects encoded data on a bit rate close to the calculated bit rate, and the encoded data switch device 602 switches and transmits the selected data.

[0090] For example, the calculated bit rate is 140 kbps, a value close to this bit rate is 128 kbps. In this case, the above switch device selects and switches encoded data reproduced from the storage medium 601b having stored therein encoded data on contents encoded at 128 kbps. In addition, if the calculated bit rate is 100 kbps, a value close to a bit rate lower than the calculated bit rate is 64 kbps. In this case, the switch device selects and switches encoded data reproduced from the storage medium 601c having stored therein encoded data on contents encoded at 64 kbps.

[0091] In this way, in the present embodiment, contents are prepared after encoded in advance for type of transmission bit rate, and a current optimal transmission rate is obtained based on network information such as packet loss rate or Jitter information from a receiver that is a function possessed by RTP. A storage medium having stored therein encoded data obtained at the bit rate corresponding to this transmission rate is selected by the switch 602, and reproduced encoded data output of the storage medium is transmitted. In this manner, there is no need for a server to carry out encode processing in real time, making it possible to reduce a load on the server. This is very effective in distributing a pre-produced video such as broadcast in particular.

[0092] Now, a modified example of the second embodiment will be described here. FIG. 7 is a block diagram depicting a method for carrying out control for a switch timing of encoded data to be inputted at the encoded data switch device 602.

[0093] Encoded data 631 is inputted to the switching position detecting device 701 and a switch device 702. Switch information 632 is inputted to the switching position detecting device 701. If there occurs a need to execute switching from the current encoded data to the other encoded data according to the switch information 632, the switching position detecting device 701 analyzes encoded data, and detects a switching enable posi-

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tion.

[0094] This means that a search is made for a frame encoded by intra-frame encoding (I-Picture).

[0095] When the switching enable position is set, an instruction for switching encoded data is supplied to the switch device 702 by using the switching instruction information 731. FIG. 8 shows an example of this instruction. Assume that encoded data A is currently selected, and there occurs a need to execute switching to encoded data B according to the switch information 632.

[0096] At this stage, assume that a frame is processed at the time of "switching instruction" shown in FIG. 8. In such a case, if encoded data is switched, an unmatched image occurs. This is because a difference from the previous image is encoded in intra-frame encoding (P-Picture). Therefore, if encoded data is switched at the time of P-Picture, an attempt is made to reproduce the next picture (picture P11 of encoded data (B)) by using immediately preceding picture (decoded picture 111 of encoding data (A)). This provides a problem that a correct decode picture cannot be obtained, and a picture is destroyed. Thus, there occurs a need to execute switching at a timing of a picture of intra-frame encoding (I-Picture) undergoing encoding by that frame only. This timing is defined as a timing at a position marked with "execute switching".

[0097] As in FIG. 9, a case in which the number of frames or time position differs depending on encoded data is considered. In this case as well, a switching enable position of encoded data at a switching destination is detected, and switching of encoded data is executed when the switching enable position is set.

[0098] At the switching position detecting device 701 shown in FIG. 7, when a need to execute switching according to the switch information 632 occurs, it is possible to employ a method for temporarily stopping an output 132 to the encoded data transmitter 103, and then, outputting new encoded data to the encoded data transmitter 103 at a stage at which the switching position is set.

[0099] This method is effective when it is necessary to suppress a buffer overflow or the like by switching encoded data. When an underflow is problematic, a stuffing bit is forcibly inserted, thereby making it possible to counteract such an underflow.

(Third Embodiment)

[0100] Now, a third embodiment according to the present invention will be described here.

[0101] The present embodiment describes an exemplary configuration of an encoding parameter determination device 401 of the video encoder 102 shown in FIG. 4 according to the first embodiment when a time interval (GOP interval) between frames encoded in a intra-frame encoded mode is adjusted based on the network condition information 136 outputted from the network state determination device 105. Here, a description will be given by focusing on differences from the first embodiment.

[0102] FIG. 13 shows an exemplary configuration of the encoding parameter determination device 401. This device comprises a GOP interval calculator (GOP interval calculator) 1501 and an encoding parameter determination device 502.

[0103] The network condition information 136 outputted from the network condition determination device 105 (including at least packet loss rate information) is input to an encoding parameter determination device 502. The parameter determination device 502 inputs packet loss rate information 1531 of the network condition information 136 to the GOP interval calculator 1501. The GOP interval calculator 1501 calculates a GOP interval from the packet loss rate information 1531. The GOP interval information 1532 is notified to the encoding parameter determination device 401. The encoding parameter determination device 401 outputs encoding parameter information 431 that contains the inputted GOP interval information 1532. When internally generated parameter information exists, the encoding parameter determination device 401 outputs GOP interval information 1532 and encoding parameter information 431 that contains the internally generated parameter information.

[0104] FIG. 14 shows an example of a method for determining a GOP interval at the GOP interval calculator.

[0105] At the step S1601, it is determined whether or not a packet loss occurs from the network condition information 136. When such a packet loss occurs, the GOP interval is estimated by formula (3) below, for example, at the step S1602.

$$Gop = (TN - TL)/\{(FN - FL) \times r\} \quad (3)$$

where "gop" denotes a GOP interval, "r" denotes a packet loss rate, FN denotes a total number of current frames, FL denotes a total number of frames during past calculation, TN denotes a time, and TL denotes a time during past calculation.

[0106] The GOP interval obtained at the step S1602 is notified to the signal processor 402 at the step S1603, and encoding is carried out based on the notified value.

[0107] On the other hand, when no packet loss has occurred at the step S1601, the default GOP thresholds are read out at the step S1604. At the step S1603, this value is notified to the signal processor 402.

[0108] According to the present embodiment, it is possible to change dynamically the GOP interval to a value suitable to a network. In this manner, when a small number of errors occur, the GOP interval is increased, thereby making it possible to reduce wasteful intra-frame encoded modes in number. In contrast, when a large number of errors occur, the GOP interval is decreased, and a frame in the intra-frame encoded mode appears quickly, thereby making it possible to acceler-

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ate recovery. In the present embodiment, it is possible to efficiently select an intra-frame encoded mode.

[0109] FIG. 15 shows another example of a method for determining a GOP interval at the GOP interval calculator in accordance with a flow chart.

[0110] In this example, even when packet loss is fewer than that in the system shown in FIG. 14, the network condition is estimated from the past history of packet loss at the step S1704, and an optimal GOP interval is calculated. This technique makes it possible to estimate whether a network is completely free of an error or an error may occurs by checking the past history instead of resetting the GOP interval to the default value by determining that no packet loss occurs at one moment. In this manner, it is possible to determine the network condition more accurately.

[0111] FIG. 16 shows still another example of a method for determining a GOP interval at the GOP internal calculator in accordance with a flow chart.

[0112] In this example, the GOP interval is determined by a unique calculation system instead of determination based on the presence/absence of a packet loss. This system can be used to determine the GOP interval from the current packet loss rate in accordance with a single formula or to determine the most suitable GOP interval by checking the past history.

[0113] The following formula (4) shows an example of calculation formula for determining the GOP interval.

$$Gop = [(TN - TL)/\{(FN - FL) \times r\}] \times \alpha \qquad (4)$$

where "gop" denotes a GOP interval, "r" denotes a packet loss rate, α denotes a sensitivity coefficient, FB denotes a total number of current frames, FL denotes a total number of frames during past calculation, TN denotes a current time, and TL denotes a time during past calculation.

[0114] In this example, the GOP interval calculated from an actual value is multiplied by a sensitivity coefficient, thereby making it possible to meet a requirement for accelerating recovery by sacrificing efficiency or a requirement when one does not take care even if an effect of error is somewhat extended. For example, if the sensitivity coefficient α is set to be smaller than 1, a GOP interval which is smaller than that calculated from an actually measured value is output. In this manner, although the efficiency is sacrificed, when an error occurs, it is possible to estimate faster recovery.

[0115] The present embodiment is not limited to formulas (3) and (4). For example, in these formulas, a value is calculated by using an increment during past calculation and subsequent, it is possible to calculate the value by taking a margin such as the n preceding increment. In this manner, it is possible to cope with a gradual change hidden in a change in detailed state or to eliminate a temporal change to some extent. Similarly, algorithms are not limited to those shown in the present embodiment.

[0116] The foregoing embodiment has described an exemplary configuration when a time interval (GOP interval) is adjusted, the time interval being between the frames encoded in the intra-frame encoded mode based on the network condition information 136 at the encoding parameter determination device 401 of the video encoder 102 shown in FIG. 4 according to the first embodiment. Alternatively, there can be provided a configuration in which the network condition determination device 105 according to the first embodiment (FIGS. 1, 2, or 3) determines a time interval (GOP interval) encoded in the intra-frame encoded mode based on information from the network information or information from the network information receiver 104 and information from the video encoder 102, and provides the encoded time interval to the image encoder 102.

[0117] As described in the first embodiment, it is possible to configure a video encoder capable of determining a network condition, the video encoder having functions of the video encoder 102 and network condition determination device 105, thereby providing the previously described functions in one block.

[0118] In the foregoing, although a variety of embodiments have been described, in short, the present invention utilizes characteristics of RTP, and comprises a system (RTCP) for notifying network state information such as jitter or packet loss rate from a transmitter or receiver. At the transmitter, a bit rate of transmission data at the transmitter is adjusted according to a transmission state of a transmission channel based on the notification of network state information acquired from the receiver in the transmitter such as jitter or packet loss rate so that control such as change of the error resilience level can be carried out. Therefore, according to the above described present invention, data can be transmitted efficiently to the maximum so as to achieve data transmission that makes it possible to fully utilize transmission requiring real time properties as well.

[0119] The techniques described in the embodiments of the present invention can be distributed to be stored as a computer executable program in a recording medium such as a magnetic disk (such as a flexible disk or a hard disk); an optical disk (such as CD-ROM, CD-R, CD-RW, DVD, or MO), and a recording medium such as a semiconductor memory. Further, the above program can be distributed by means of transmission via a network.

[0120] According to the present invention, it is possible to determine a network condition, and then, optimally set an encoding parameter. In addition, when a packet loss caused by congestion and a loss of a channel error coexist in a network, it is possible to determine the loss, and then, to set a parameter.

[0121] Therefore, according to the present invention, there can be provided a data transmission apparatus and method in which data can be transmitted efficiently to the maximum so as to achieve data transmission that

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makes it possible to fully utilize transmission requiring real time properties.

Claims

1. A data transmission apparatus for transmitting transmission data from a transmitter to a receiver via a transmission channel, **characterized by** comprising:

   means (105) for estimating a transmission condition of the transmission channel in the transmitter based on at least Jitter information or a packet loss rate obtained from the receiver; and
   means (102) for changing at least one of a bit rate of transmission data and an error resilience level according to the estimated transmission condition.

2. An apparatus according to claim 1, **characterized in that** the transmitter includes means (102) for generating encoded data obtained by encoding a single content at different transmission rates, and means (603) for selecting optimum encoded data having optimum bit rate from the encoded data of the encoded data generating means (102) to adjust a bit rate of the transmission data in the transmitter according to the estimated transmission condition.

3. A data transmission method of transmitting transmission data from a transmitter to a receiver via a transmission channel, **characterized by** comprising:

   generating encoded data obtained by encoding a single content at different transmission rates;
   estimating a transmission condition of the transmission channel in the transmitter based on at least Jitter information or a packet loss rate obtained from the receiver; and
   selecting optimum encoded data having an optimum bit rate from the encoded data to adjust a bit rate of the transmission data in the transmitter according to the estimated transmission condition.

4. A data transmission method **characterized by** comprising:

   estimating a transmission condition of the transmission channel in the transmitter based on at least Jitter information or a packet loss rate obtained from the receiver; and
   changing at least one of a bit rate of transmission data and an error resilience level according to the estimated transmission condition.

5. A data transmitting apparatus that transmits transmission data from a transmitter to a receiver via a transmission channel, **characterized by** comprising:

   means (102) for generating plural encoded data obtained by encoding a single content at different bit rates, in the transmitter;
   means (105) for estimating a condition of the transmission channel based on Jitter information or packet loss rate; and
   means (603) for selecting encoded data having an optimum transmission rate from the plural encoded data according to the estimated transmission condition.

6. A method of transmitting transmission data from a transmitter to a receiver via a transmission channel, the method **characterized by** comprising:

   storing plural encoded data obtained by encoding a content at different bit rates;
   estimating a condition of the transmission channel based on Jitter information or packet loss rate;
   selecting encoded data having optimum transmission rate from the plural encoded data to adjust a bit rate of the transmission data in the transmitter.

7. A data transmission program stored on a computer readable medium, the program **characterized by** comprising:

   instruction means for instructing a computer to estimate a transmission condition of the transmission channel in the transmitter based on at least Jitter information or a packet loss rate obtained from the receiver; and
   instruction means for instructing the computer to change at least one of a bit rate of transmission data and a error resilience level according to the estimated transmission condition.

8. A data transmission apparatus, **characterized by** comprising:

   receiver means (104) for receiving network information regarding a condition of a network;
   determination means (105) for determining a network condition based on the network information from the receiver means;
   encoder means (102) for encoding a video data signal to generate encoded video data and control a bit rate or an error resilience level of the encoded video data according to the network condition information; and
   transmitter means (103) for transmitting the en-

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coded video data to the network.

9. An apparatus according to claim 6, **characterized in that** the encoder means (102) is supplied with an encoding parameter as the network condition information and generates encoded data whose bit rate is adjusted according to the encoding parameter,

the determination means (105) includes first storage means (302) for storing encoding parameter information obtained by the encoder means, second storage means (301) storing the network information input by the network information receiver, and determination means (303) for determine the encoding parameter by deciding the network condition based on network information input by the network information receiver, past encoding parameter information from the first storage means and past network information from the second storage means.

10. An apparatus according to claim 8, **characterized in that** the encoder means (102) includes parameter determination means (401) for determining the encoding parameter from the network condition information input from the receiver means, the encoder means (102) encoding the video data signal to generate the encoded video data whose bit rate is adjusted in correspondence with the encoding parameter determined by the determination means (401).

11. An apparatus according to claim 10, **characterized by** including encoding determination means (501) determine whether a next frame is to be encoded forcibly in an intra-frame encoding mode, when the parameter determination means (401) determines the encoding parameter using the network condition information.

12. An apparatus according to claim 8 or 9, **characterized in that** the determination means (105) includes computation means for computing a GPO interval from the network information input from the receiver means (104) to generate network condition information including GOP interval information indicating the GOP interval obtained by the computation means, and the encoder means (102) encodes the video data signal according to the GOP interval information included in the network condition information.

13. An apparatus according to claim 8 or 10, **characterized in that** the encoder means (102) includes GOP interval computation means for computing a GOP interval based on the network information input from the receiver means (104) and encodes the video data signal according to the GOP interval information indicating the GOP interval computed by the GOP interval computation means.

14. An apparatus according to claim 12 or 13, **characterized in that** the determination means (105) determines at least a packet loss rate as the network condition, and the GOP interval computation means computes the GOP interval based on at least the packet loss rate.

15. An apparatus according to claim 8, **characterized by** including switching means (602) for switching among plural encoded data encoded at different transmission rates, respectively, to select encoded data having a transmission rate corresponding to switching information, and selector means (603) for selecting a transmission rate of encoded data to be transmitted from the transmitter based on the network condition information outputted from the determination means (105) and output the selected transmission rate as the switching information to the switching means.

16. An apparatus according to claim 15, **characterized in that** the switching means (602) includes a switching position detector for detecting a switching position at which one of the encoded data can be switched to the other, and when an encoded data switching signal is generated by the switching information output from the selector means (603), the switching position detector detects the switching position, to switch the encoded data at the switching position.

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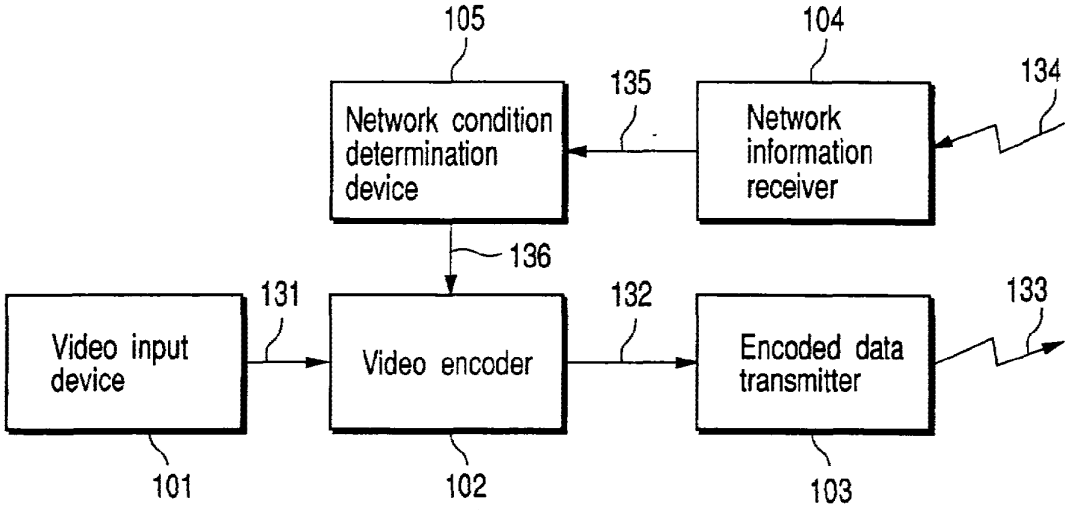


FIG. 1

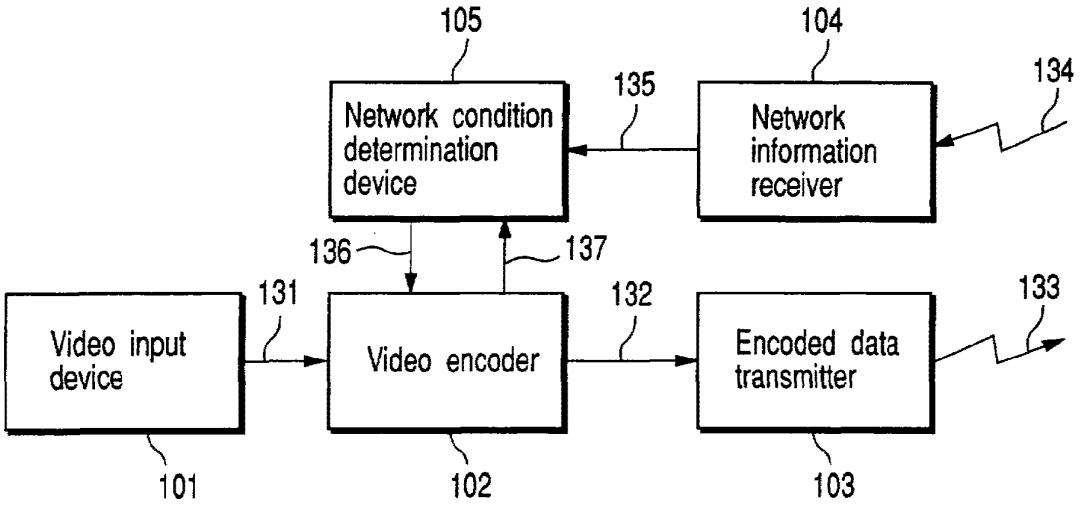


FIG. 2

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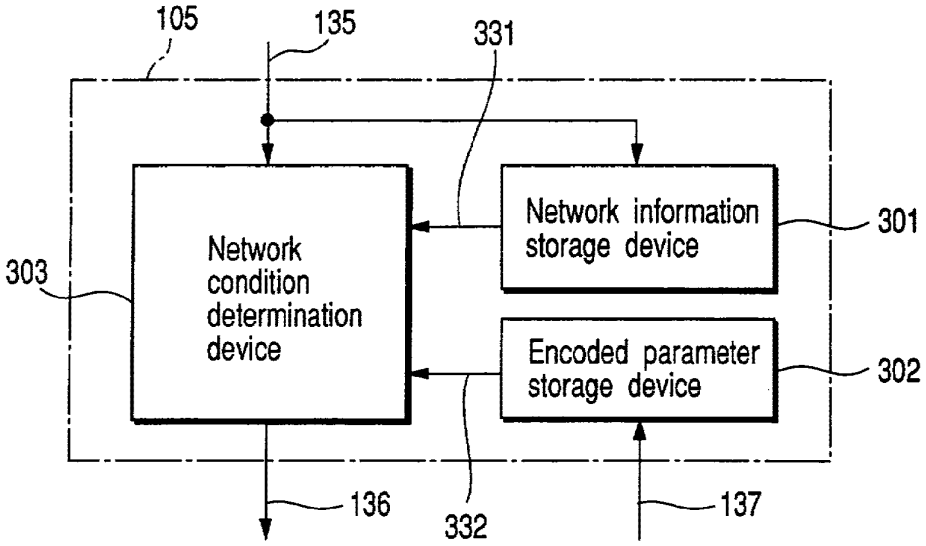


FIG. 3

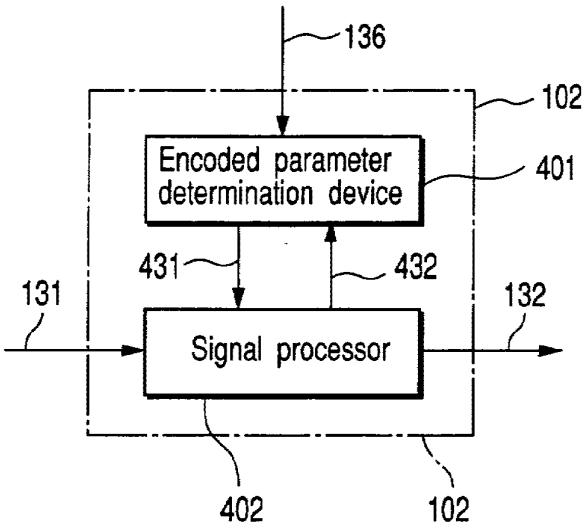


FIG. 4

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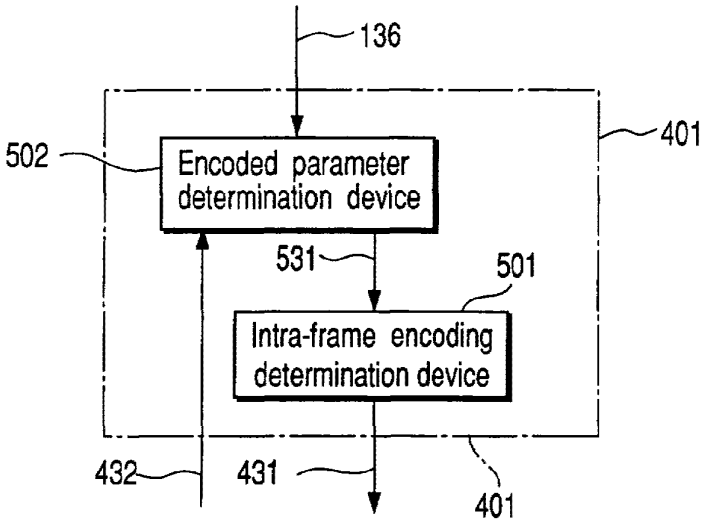


FIG. 5

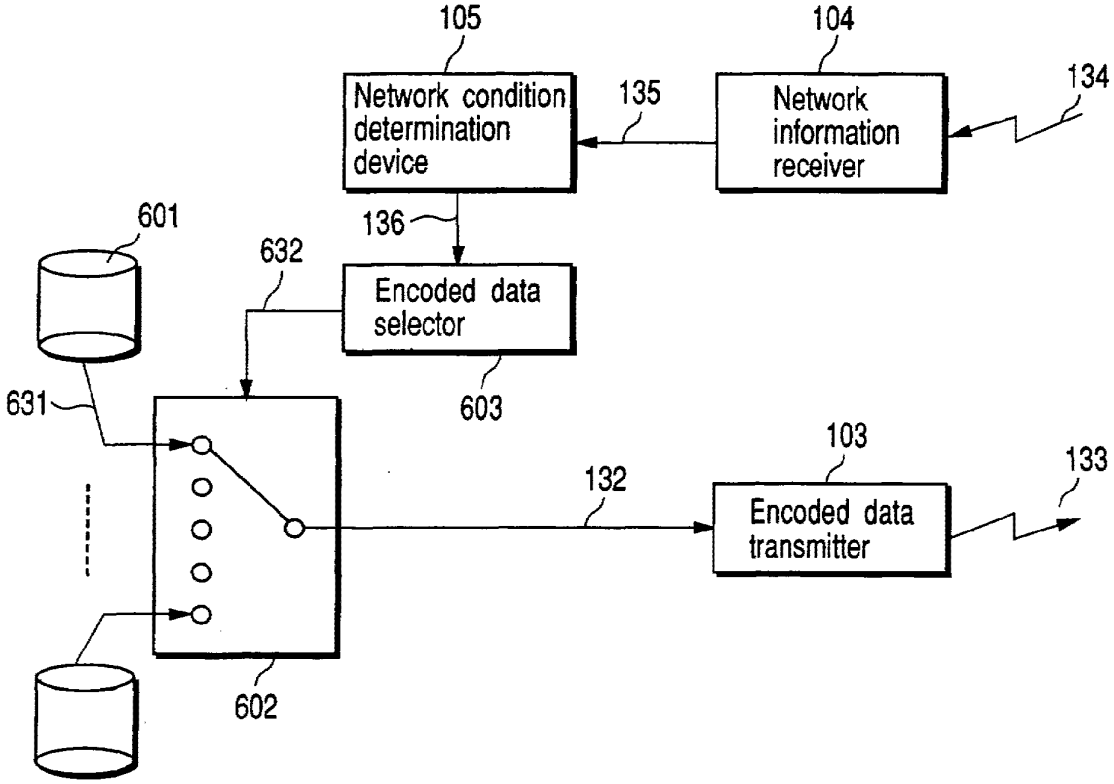


FIG. 6

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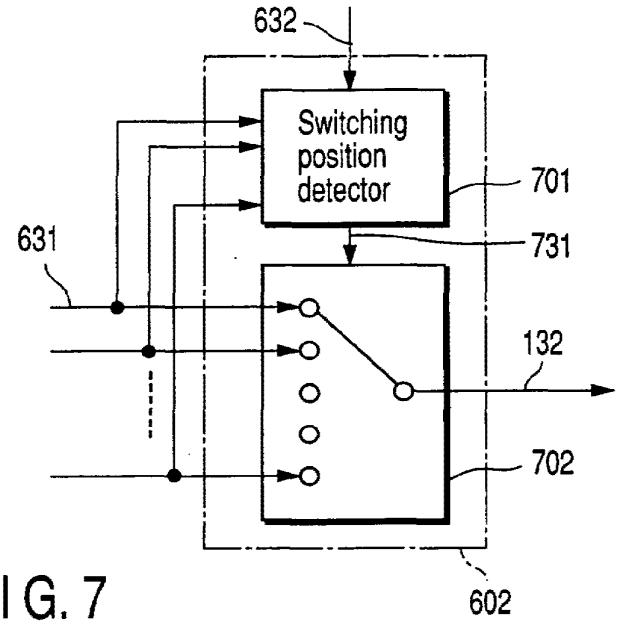


FIG. 7

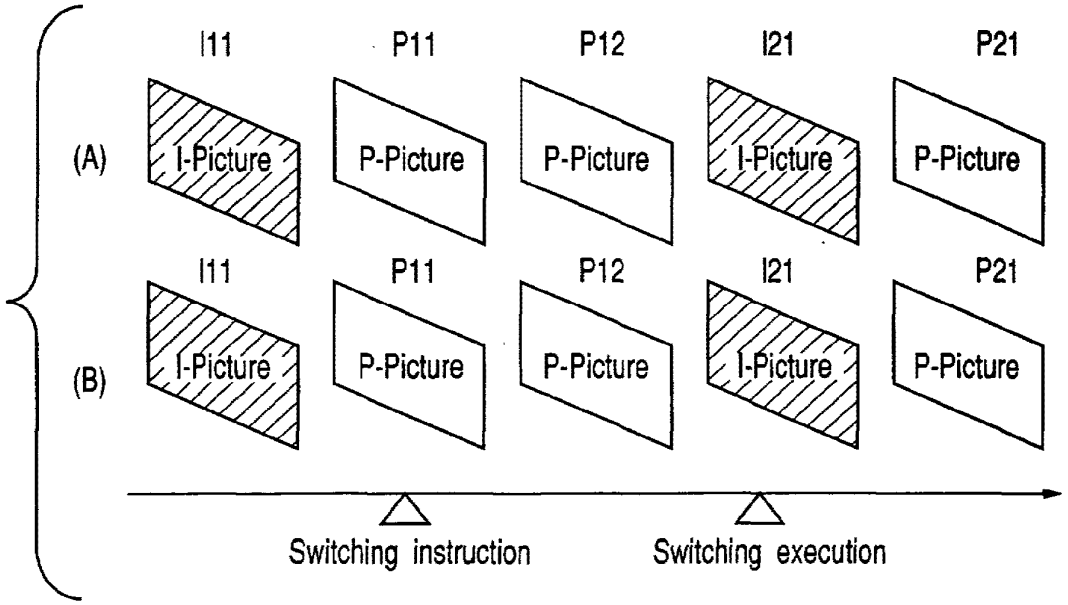


FIG. 8

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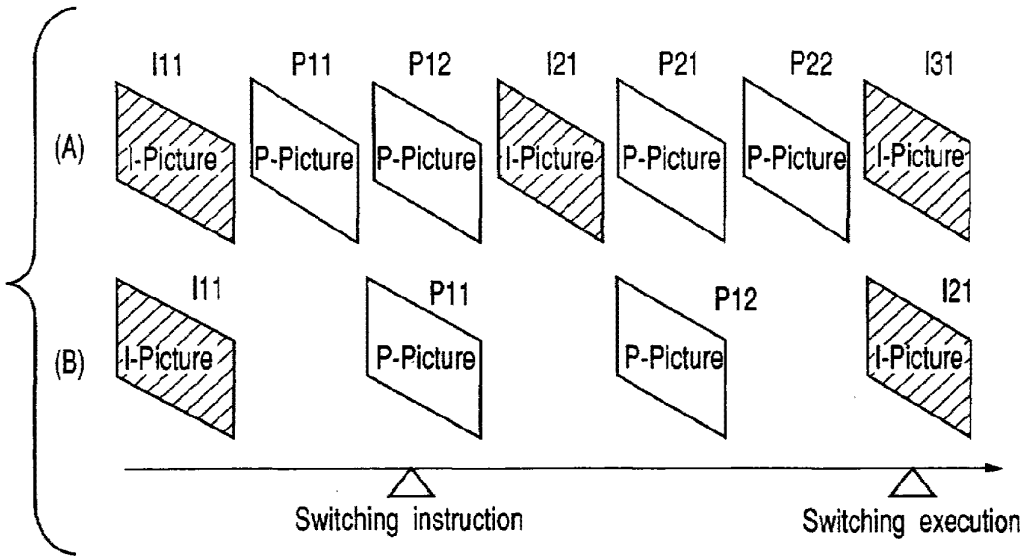


FIG. 9

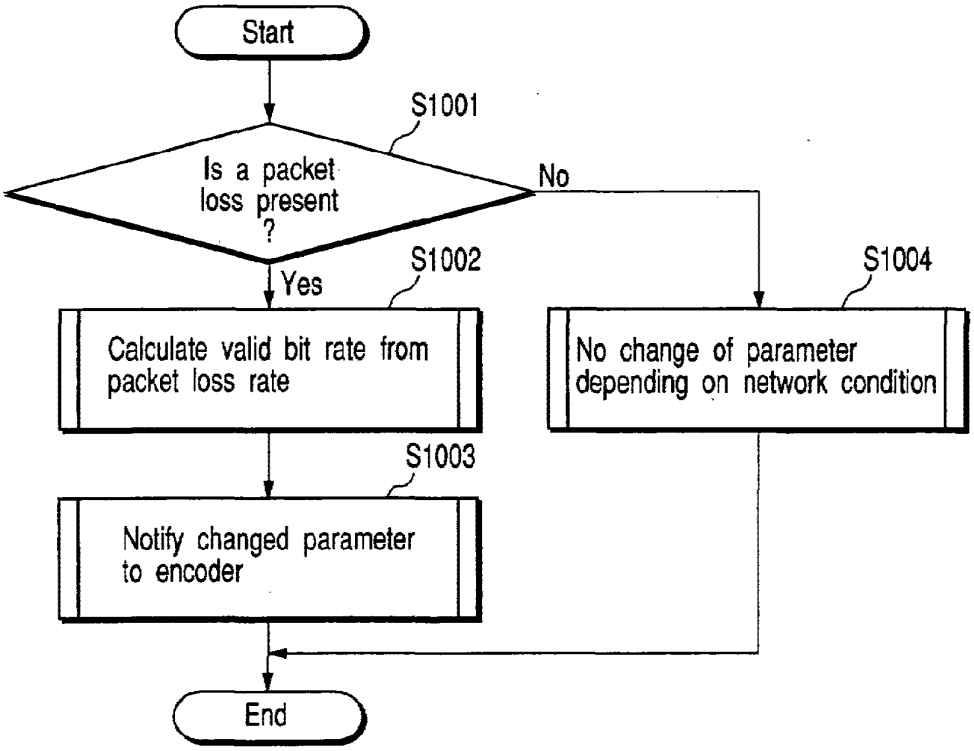


FIG. 10

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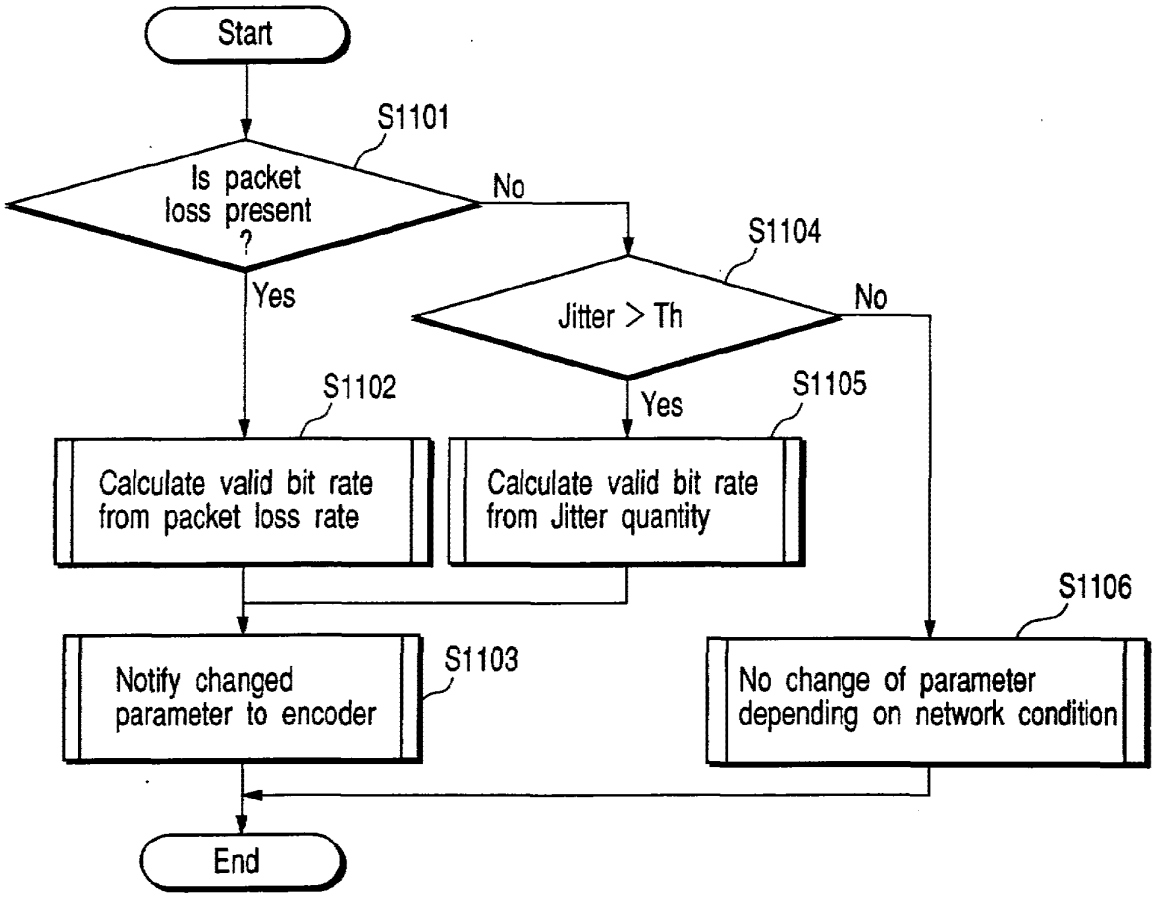


FIG. 11

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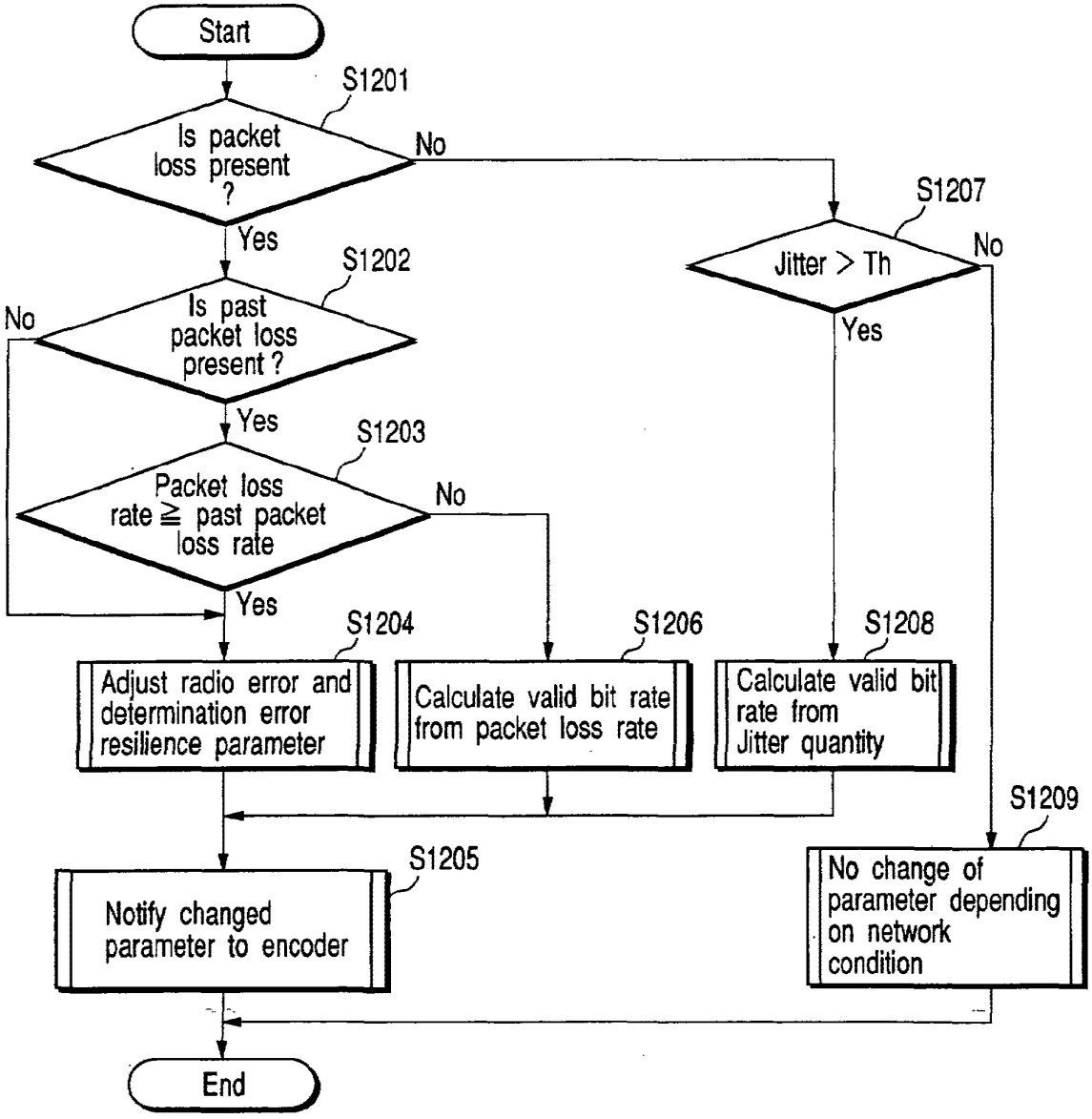


FIG. 12

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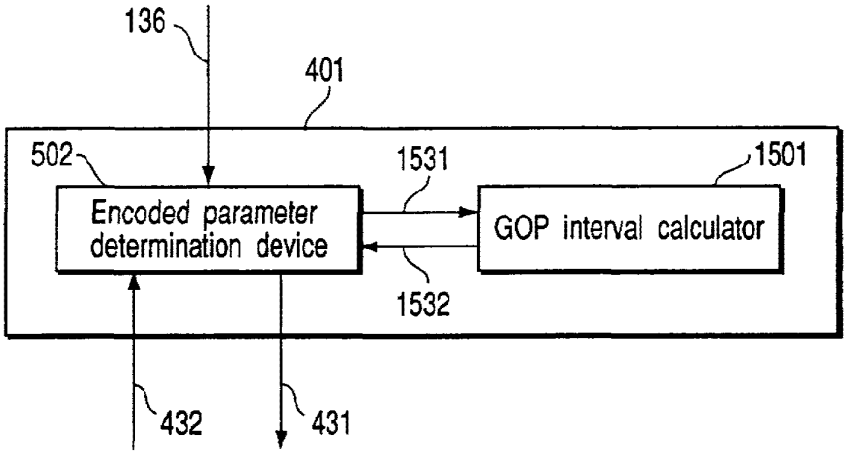


FIG. 13

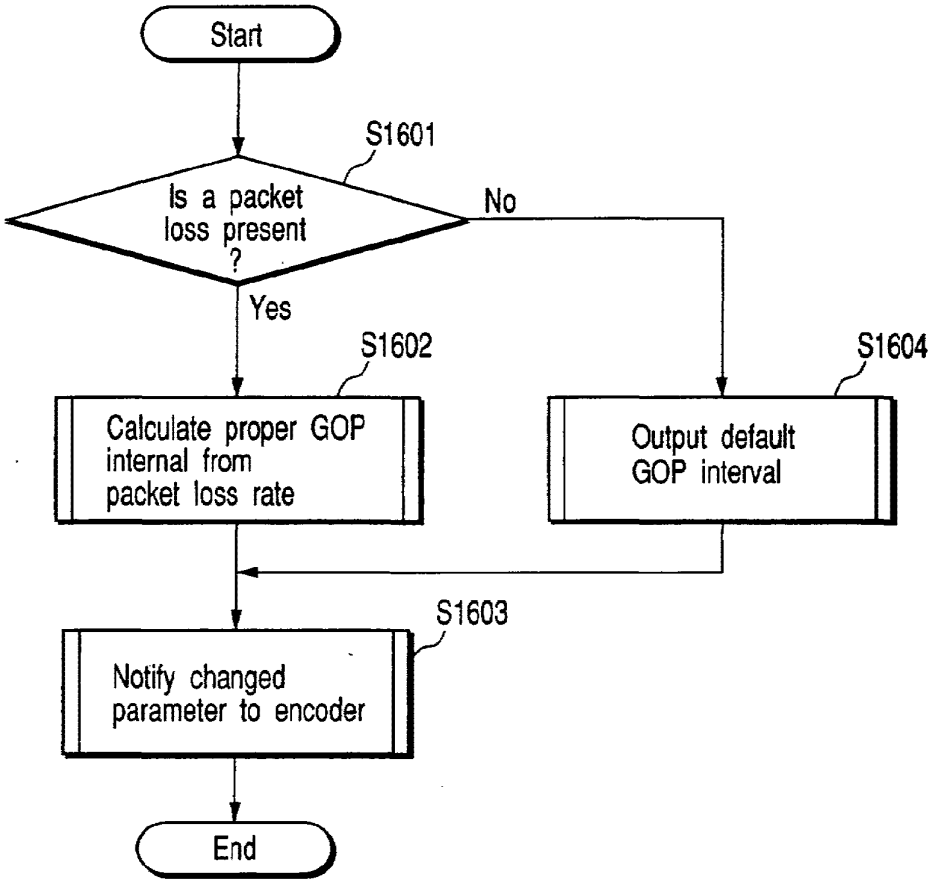


FIG. 14

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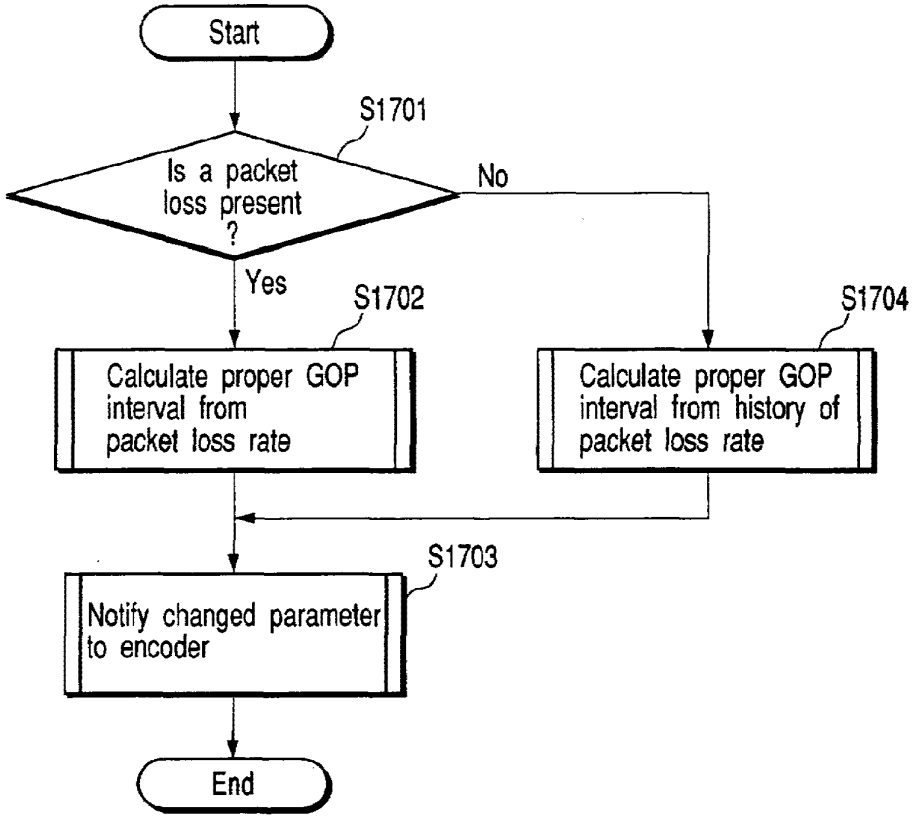


FIG. 15

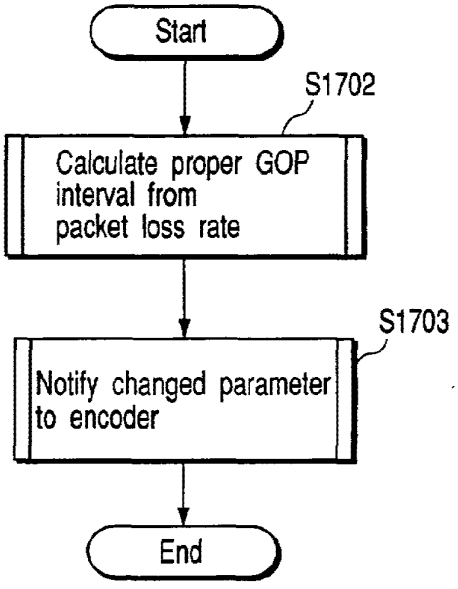


FIG. 16

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(54) A system and process for controlling the coding bit rate of streaming media data

(57) A system and process for controlling the coding bit rate of streaming media data is presented. This coding bit rate control involves dynamically adjusting the coding bit rate to control client buffer duration to prevent the buffer from underflowing, while keeping the average coding bit rate close to the average transmission bit rate of the network (an thus maximizing the quality of the data playback). Using the theory of optimal linear quadratic control, the client buffer duration is kept as close as possible to a target level while still keeping the coding bit rate (and hence the quality) as constant as possible. In addition, a leaky bucket model is incorporated into the control loop so that the changes in buffer duration due to natural variation in the instantaneous coding bit rate are not mistaken for changes in buffer duration due to network congestion.

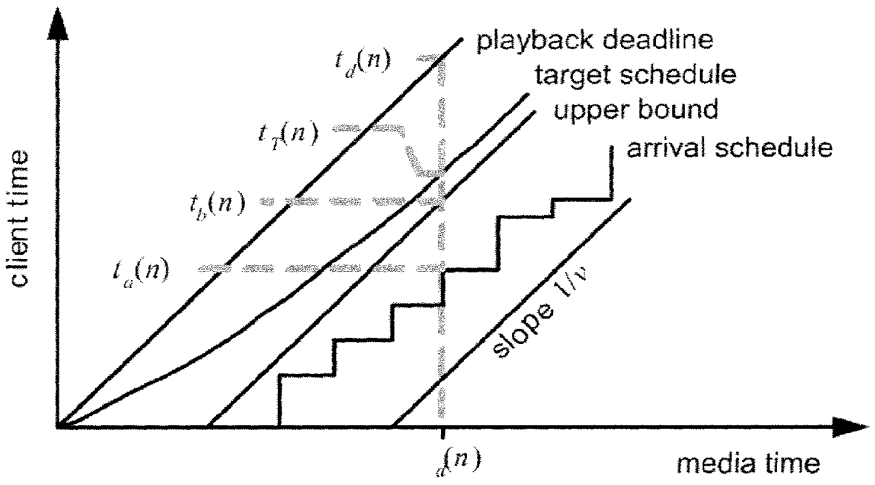


FIG. 5

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Description

BACKGROUND

Technical Field:

[0001] The invention is related to controlling the coding bit rate of streaming media, and more particularly to a system and process for controlling the coding bit rate of streaming media data that provides fast startup, continuous playback, and maximal quality and smoothness over the entire streaming session.

Background Art:

[0002] Perhaps the major technical problem in streaming media on demand over the Internet is the need to adapt to changing network conditions. As competing communication processes begin and end, the available bandwidth, packet loss and packet delay all fluctuate. Network outages lasting many seconds can and do occur. Resource reservation and quality of service support can help, but even they cannot guarantee that network resources will be stable. If the network path contains a wireless link, for example, its capacity may be occasionally reduced by interference. Thus it is necessary for commercial-grade streaming media systems to be robust to hostile network conditions. Moreover, such robustness cannot be achieved solely by aggressive (nonreactive) transmission. Even constant bit rate transmission with re-transmissions for every packet loss cannot achieve a throughput higher than the channel capacity. Some degree of adaptivity to the network is therefore required.

[0003] End users expect that a good streaming media system will exhibit the following behavior: content played back on demand will start with low delay; once started, it will play back continuously (without stalling) unless interrupted by the user; and it will play back with the highest possible quality given the average communication bandwidth available. To meet these expectations in the face of changing network conditions, buffering of the content at the client before decoding and playback is required.

[0004] Buffering at the client serves several distinct but simultaneous purposes. First, it allows the client to compensate for short-term variations in packet transmission delay (i.e., "jitter"). Second, it gives the client time to perform packet loss recovery if needed. Third, it allows the client to continue playing back the content during lapses in network bandwidth. And finally, it allows the content to be coded with variable bit rate, which can dramatically improve overall quality. Note that even so-called constant bit rate (CBR) coded content is actually coded with variable bit rate within the constraints of a decoding buffer of a given size. The larger the decoding buffer size, the better the quality. The required decoding buffering is part of the larger client buffer.

[0005] The size of the client buffer can be expressed as the number of seconds of content in the buffer, called the buffer *duration.* The buffer duration tends to increase as content enters the buffer and tends to decrease as content leaves the buffer. Content leaves the buffer when it is played out, at a rate of v seconds of content per second of real time, where v is the *playback speed* (typically 1 for normal playback, but possibly more than 1 for high speed playback or less than 1 for low speed playback). Content enters the buffer when it arrives at the client over the network, at a rate of r_a/r_c seconds of content per second of real time, where r_a is the *arrival rate,* or average number of bits that arrive at the client per second of real time, and r_c is the *coding bit rate,* or the average number of bits needed to encode one second of content. Thus the buffer duration can be increased by increasing r_a, decreasing r_c, and/or decreasing v (and vice versa for decreasing the buffer duration). Although the buffer duration can be momentarily controlled by changing r_a or changing v, these quantities are generally not possible to control freely for long periods of time. The arrival rate r_a on average is determined by the network capacity, while the playback speed v on average is determined by user preference. Thus if the network capacity drops dramatically for a sustained period, reducing the coding bit rate r_c is the only appropriate way to prevent a *rebuffering event* in which playback stops (v=0) while the buffer refills.

[0006] Thus, adaptivity to changing network conditions requires not only a buffer, but also some means to adjust the coding bit rate r_c of the content. This can be done by stream switching in combination with multi bit rate (MBR) coding or coarse grained or fine grained scalable coding. Today's commercial streaming media systems [1] rely on MBR coding as well as *thinning,* which is a form of coarse grained scalability. In MBR coding, semantically identical content is encoded into alternative bit streams at different coding bit rates and stored in the same media file at the server, allowing the content to be streamed at different levels of quality corresponding to the coding bit rates r_c, possibly using bit stream switching [2]. In coarse grained scalable coding (such as MPEG-2/4 temporal or SNR scalability) the content is encoded into several sub-streams or *layers,* so that the coding bit rate r_c can be changed in large deltas by adding or dropping (at possibly restricted times) one layer of content at a time. Thinning is a special case of coarse grained scalability in which dependent video frames (P and B frames) are dropped before independent video frames (I frames), which are in turn are dropped before audio frames. Future commercial systems may support fine grained scalability (FGS) as well. Fine grained scalable coding (such as 3D SPIHT [6], MPEG-4 FGS [7], or EAC [8]) allows the coding bit rate r_c to change

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at any time in deltas sometimes as small as one byte per presentation. FGS coding offers great flexibility in adapting to variable network conditions, and can demonstrably improve quality under such conditions.

[0007] Some examples of existing technology that adjusts the coding bit rate r_c of the content in an attempt to adapt to changing network conditions includes de Cuetos and Ross [9], which decouples the transmission rate and the coding bit rate. They assume that the transmission rate is determined by the network transport protocol (TCP or TFRC). Based on this, they develop a heuristic real time algorithm for adaptive coding bit rate control and compare its performance to an optimal offline coding bit rate control policy if the transmission rate is given prior to streaming. The work of Rejaie, Handley and Estrin [4] proposes a scheme for transmitting layered video in the context of unicast congestion control, which basically includes two mechanisms. One mechanism is a coarse-grained mechanism for adding and dropping layers (changing the overall coding bit rate and quality). The other is a fine-grained interlayer bandwidth allocation mechanism to manage the receiver buffer (not changing the overall coding bit rate or quality). A potential issue with this approach is that it changes the coding bit rate by adding or dropping one (presumably coarse) layer at a time. If the layers are fine-grained, as in the case of FGS coded media, then adding or dropping one (fine-grained) layer at a time typically cannot provide a prompt enough change in coding bit rate. Moreover, since the adding and dropping mechanism is rather empirical, the mechanism may simply not be suitable for FGS media. The work of Q. Zhang, Zhu and Y-Q. Zhang [5] proposes a resource allocation scheme to adapt the coding bit rate to estimated network bandwidth. The novelty of their approach is that they consider minimizing the distortion (or equivalently maximizing the quality) of all applications, such as file-transfers and web browsing in addition to audio/video streaming. However, their optimization process does not include the smoothness of individual streams and might lead to potential quality fluctuations.

[0008] However, even with buffering and the ability to adjust the coding bit rate, existing technologies for streaming media on demand over the Internet suffer from two problems:

1. Playback often stalls during network congestion. That is, during playback of high bit rate content, if the network bit rate drops below the content bit rate, the client buffer runs out of content and playback stops while the client rebuffers (known as a "rebuffering" event).
2. Start-up delay is often too long (about 5 seconds).

There are existing solutions to both of these problems, but they do not always work well. One solution to the first problem is to stream the content encoded at a coding bit rate that is low relative to the average bit rate transmitted over the network (the *transmission bit rate*). This will enable the buffer to build up over time. With such a large reserve of unplayed information on the client, temporary network congestion will not affect playback. However, this solution has two problems. First, the coding bit rate of the content is not as high as the average transmission bit rate of the network and hence the quality is lower than it could be. Second, the buffer can grow nearly as large as the streamed file itself. This may demand too many resources on the client device.

[0009] Another solution to the first problem is to try to maintain the client buffer at a constant level (typically about 10 seconds), while switching between different coding bit rates for the same content, trying to match the transmission bit rate of the network. However, rebuffering events are still commonly observed in practice, because choosing the right time to switch streams is difficult. One reason that it is difficult is that there are natural variations in the instantaneous coding bit rate of the content, even in so-called constant bit rate encodings, which can confuse the client buffer management algorithm.

[0010] The second problem above (long start-up delay) also has multiple solutions. One solution is to fill up the client buffer quickly, with a quick initial transmission rate burst. With the client buffer full, playback can safely begin. However, this solution has several problems. First, it is only applicable when there is sufficient "headroom" in the network to increase the transmission bit rate for a few seconds. Thus it is usually not applicable for modem connections, for example. Second, it stresses the network, causing other applications in the network to back off. It has been shown that during the burst period, there can be as much as 80% packet loss, causing all TCP connections sharing the same bottleneck to back off. Third, by implication, if there is headroom in the network for bursting, then the streaming application may not be using the full bandwidth available to it during the remainder of the file, meaning that quality is lower than it should be.

[0011] Another solution to the second problem is to play back the content slower than real time, allowing playback to begin while the client buffer builds up. This is an innovative solution, but has the obvious temporal distortion.

[0012] A final solution to the second problem is to lower temporarily the coding bit rate of the content below the transmission bit rate of the network, allowing playback to begin while the client buffer builds up. This is a solution proposed by Chou et al. in [13].

[0013] The system and process of the present invention resolve the problems of the existing techniques and provide fast startup, continuous playback, and maximal quality and smoothness over the entire streaming session.

[0014] It is noted that in the preceding paragraphs, as well as in the remainder of this specification, the description refers to various individual publications identified by a numeric designator contained within a pair of brackets. For example, such a reference may be identified by reciting, "reference [1]" or simply "[1]". A listing of references including

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the publications corresponding to each designator can be found at the end of the Detailed Description section.

SUMMARY

[0015] The present invention is directed toward a system and process for controlling a coding bit rate of streaming media data being transmitted to a client from a server over a computer network. In general, this coding bit rate control involves dynamically adjusting the coding bit rate of the streaming media data to control the client buffer duration. The purpose of this is to prevent the client buffer from underflowing, while keeping the average coding bit rate close to the average transmission bit rate of the network (an thus maximizing the quality of the playback of the data). The problem of coding bit rate control is formulated as a standard problem in linear quadratic optimal control, in which the client buffer duration is controlled as closely as possible to a target level. The smoothness of the average coding bit rate over consecutive frames is also considered when deciding whether to change the coding bit rate as part of the optimal control process. This yields a higher and more stable quality as network conditions change. In addition, the natural variation in the instantaneous coding bit rate that occurs for a given average coding bit rate is explicitly take into consideration. This is accomplished by incorporating the leaky bucket model into the control loop so that the changes in buffer duration due to natural variation in the instantaneous coding bit rate are not mistaken for changes in buffer duration due to network congestion. It is noted that in the present system and process, it is not the actual fullness of the client buffer that is controlled, but an upper bound on the time of arrival of bits into the client buffer, to a target level. The upper bound is based on the leaky bucket model of the coding bit rate.

[0016] Preventing the client buffer from underflowing, while keeping the average coding bit rate close to the average transmission bit rate of the network, meets two of the aforementioned user expectations. Namely, if the buffer never underflows, it allows for continuous playback. In addition, keeping the average coding bit rate close to the average transmission bit rate of the network means the data is played back with the highest possible quality given the average communication bandwidth available. This leaves the remaining issue of startup delay. This issue is resolved in the present system and process by controlling the size of the client buffer over time. More particularly, the aforementioned client buffer target level is adjusted to start small, and then grow slowly over time. If the buffer is initially small, it allows for shorter startup delay. In addition, as the buffer is eventually allowed to grow large, it enhances the robustness of the system as well as creating high, nearly constant quality. Thus, client buffer management is a key element affecting the performance of streaming media systems.

[0017] More particularly, the present system and process involves a server generating a streaming media data stream that exhibits one of a number of coding bit rates supported by the server. Initially, the server chooses the coding bit rate during a startup period. However, after the startup period, the client provides coding bit rate requests to the server. In response, the server transmits the streaming media data at the most appropriate supported coding bit rate closest to the rate requested by the client. The coding bit rates requested by the client are those estimated to provide a high quality playback of the streaming media data while still keeping a decoder buffer of the client used to receive streaming media data from the server filled to a desired duration level.

[0018] The client computes the coding bit rate that will provide the desired results on an ongoing basis using the aforementioned linear quadratic optimal control technique. This coding bit rate computation involves determining on a frame-by-frame basis a coding bit rate that reduces a difference between an estimated latest anticipated arrival time of the frame under consideration and a prescribed target arrival time, while at the same time reducing the change in the coding bit rate to a prescribed degree. In one embodiment involving the aforementioned leaky bucket model, the coding bit rate computations are based on parameters indicative of the state of the encoder buffer of the server. These parameters are computed by the server and provided to the client along with the streaming media data.

[0019] More particularly, the server first computes a set of parameters defining an initial state of the encoder buffer as it would exist if a data stream corresponding to a supported coding bit rate where streamed therefrom. A separate set of parameters is computed for each of the supported coding bit rates, and are provided to the client in a preamble to the streaming media data. These parameters include the coding bit rate associated with the data stream, the size of the encoder buffer employed with the coding bit rate of the data stream, and a value indicative of the initial encoder buffer fullness exhibited at the coding bit rate of the data stream. It is noted that the size of the encoder buffer employed with each supported coding bit rate varies and is chosen so as to be the minimum size buffer that will still contain the data stream at any point in the streaming process given the coding bit rate and the initial encoder buffer fullness.

[0020] In addition to the initial encoder buffer parameters, the server also computes an upper bound gap for each frame of the streaming media data generated for each coding bit rate supported by the server. This upper bound gap is defined as the number of data bits that the server's encoder buffer can contain over the bits currently contained therein after a just-generated frame is fully input into the buffer. More particularly, the upper bound gap for each frame is computed as the difference between the encoder buffer size and the last computed value for an encoder buffer fullness after insertion of the just-generated frame. The encoder buffer fullness value after insertion of the just-generated frame is computed as the sum of the last computed value of the encoder buffer fullness value prior to insertion of the just-

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generated frame and the size of that just-generated frame. The encoder buffer fullness value prior to insertion of the just-generated frame is computed as either zero, or the difference between the value computed for the encoder buffer fullness after the insertion of the frame generated immediately before the just-generated frame and the coding bit rate associated with that prior frame divided by the instantaneous frame rate associated with said prior frame, whichever is larger. The instantaneous frame rate is equal to the reciprocal of, the time the next frame is scheduled to be encoded less the time the just-generated frame was encoded. In one embodiment, the server provides the upper bound gap computed for the first frame of a sequence of frames generated after a change in the coding rate to the client along with an indication of the coding bit rate associated with the sequence of frames as part of the data associated with the first frame of the sequence. In another embodiment, the server provides the gap value with every frame generated.

[0021] The client employs the encoder buffer parameters and the upper bound gap values to determine on a frame-by-frame basis the coding bit rate that will reduce a difference between the estimated latest anticipated arrival time of a frame under consideration and a prescribed target arrival time of that frame, in order to keep the client buffer at approximately the desired duration level. In cases where the upper bound gap is only provided with the first frame after a change in the coding bit rate, the client estimates the upper bound gap for the frames that do not include a gap value. It is also noted that given the aforementioned initial encoder buffer conditions, it is possible for the client to estimate the upper bound gap values for every frame received. Thus, an alternate embodiment where the server is not configured to compute and provide the gap values on an ongoing basis, the client computer can still compute them on its own.

[0022] When a frame with a new average coding bit rate arrives at the client there is a shift in the upper bound gap. This shift can be on the order of seconds and hence, rather than being negligible, can be confusing to the controller. One solution to this is to introduce a simultaneous shift in the control target schedule. To this end, the server also computes a shift value for each frame representing the first frame after a coding bit rate change. This shift value represents the difference between the upper bound gap that would be associated with the frame generated immediately before this first frame had it been encoded at the new coding bit rate and the upper bound gap actually associated with the frame as encoded at the previous coding bit rate. The shift value is provided to the client along with the first frame after a change in the coding bit rate. The client shifts the currently scheduled target arrival time associated with the just received "first" frame by the shift value provided, and the currently scheduled target arrival times for future frames are shifted such that they collectively approach, over a period of time, and eventually coincide with, the previous target arrival times for those frames. In this way the adverse effects of an upper bound gap shift when the coding bit rate is changed are mitigated and the target arrival time values are eventually brought back in line.

[0023] In regard to the target arrival time for each frame, these are chosen so as to make the amount of time between the target time of a frame and its playback time large enough, after the startup period, that network jitter, delays and throughput changes which may cause the actual arrival time of the frame to be after its target arrival time do not result in the frame arriving after its scheduled playback time. During the startup period, the target arrival times are chosen so as to make the target arrival time closer to the playback time to assist in reducing startup delay. In one embodiment this is accomplished by setting the target arrival time for each frame using a logarithmic target schedule. In another embodiment this is accomplished by setting the target arrival time for each frame using a two-piece linear target schedule where the difference between the target arrival time and the playback time for a frame arriving during the startup period increases linearly to a prescribed amount of time that is large enough to account for the network jitter, delays and throughput changes and after which the difference remains substantially constant.

[0024] It is noted that the startup delay can be further minimized by beginning playback of the first frame of the streaming media data when the client's decoder buffer has the minimum amount of data therein that is needed to ensure an underflow condition does not occur at the initial coding bit rate. Still further, the initial coding bit rate can be set to a level that is less than the anticipated arrival rate of the streaming media data at the client since the minimum amount of data needed to ensure an underflow condition does not occur, decreases as the arrival rate increases relative to the coding bit rate. Thus, in the startup period before the client request changes in the coding bit rate, the server provides the streaming media data at the initial coding bit rate. In one embodiment, the initial coding bit rate is set to approximately one-half the anticipated arrival rate, where the anticipated arrival rate is estimated to be the anticipated transmission rate from the server at the current bandwidth available on the network. It is noted that the startup period can be defined as the period of time prior to the first instance of an estimated latest arrival time of a frame under consideration computed for the initial coding bit rate being earlier than a target arrival time for that frame.

[0025] In regard to the client identifying the coding bit rate for each frame that also reduces the change in the coding bit rate to a prescribed degree, it is noted that the prescribed degree can vary depending on whether the coding bit rate increased. If it did increase, then the prescribed degree to which any future change in the coding bit rate is minimized is made greater in comparison to the prescribed degree in cases where the last change in the coding bit rate decreased the rate. Still further, it is also desirable to minimize quality variations due to large or frequent changes to the coding bit rate. In order to stabilize the code bit rate changes, the following actions can be taken. First, in the case where the client identifies a new coding bit rate that represents an increase, a new coding bit rate would be requested from the server only if the new rate does not exceed the current moving average arrival rate of the frames. In another embodiment, the

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new coding bit rate representing an increase would only be requested from the server, even if it exceeds the current moving average arrival rate of the frames, if the current client buffer duration exceeds the desired duration level by an amount that it is estimated will not be expended at the higher coding bit rate prior to the passing of a prescribed period of time (e.g., 60 seconds). However, in a case where the client identifies a new coding bit rate that represents a decrease, a new coding bit rate would be requested from the server even if it represents a significant departure from the immediately previous coding bit rate. This is because there is little risk in the client buffer underflowing when the coding rate is decreased.

[0026] In regard to the aforementioned moving average arrival rate of the frames, a new procedure for computing this rate is employed with the present system and process. More particularly, the moving average arrival rate is computed on a packet-by-packet basis, by calculating the product of the moving average arrival rate computed for the immediately preceding packet to a currently received packet and a fractional weighting factor, added to the product of the instantaneous arrival rate of the currently received packet and one minus the fractional weighting factor. In this computation, the fractional weighting factor is not a constant as in the past, but instead is based on the inter-arrival gaps between received packets. More particularly, the fractional weighting factor $\beta(k)$ for a currently received packet k is computed as $\frac{e^{-\alpha[t(k)-t(k-1)]}-e^{-\alpha[t(k)-t(0)]}}{1-e^{-\alpha[t(k)-t(0)]}}$ where α is the reciprocal of a prescribed time constant, $t(k)$ is the actual arrival time of the current packet, $t(k\text{-}1)$ is the actual arrival time of the packet received immediately prior to the current packet, and $t(0)$ is the arrival time of the first packet of the streaming media data. In this case, the instantaneous arrival rate $r_a(k)$ of the current packet k is computed as $\frac{b(k)}{t_a(k)-t_a(k-1)}$, where $b(k)$ is the size of the current packet. If $b(k)$ is expressed in bits and $t_a(k) - t_a(k - 1)$ is expressed in seconds, then the moving average arrival rate represents the arrival rate of the streaming media data bit bits per second. It is noted that a similar procedure can be employed for any arbitrary units of rate of the streaming media.

[0027] As mentioned previously, the server generates data streams that exhibit one of a number of coding bit rates supported by the server, and transmits data streams at the most appropriate supported coding bit rate closest to the rate requested by the client. The number of available coding bit rates will depend on how the data is encoded. For example, if a fine grain scalable coding scheme is used theoretically there could be a large number of rates available (although for practical reasons the number is more likely to be lower, e.g., 50). However, if a coarse grain scalable coding scheme or a multiple bit rate coding scheme is employed, there could be a more limited number of coding bit rates available from the server. Thus, in some cases an optimum coding bit rate identified by the client may not be available from the server. In addition, even if there is a matching coding bit rate available, the upper bound gap may be such that switching to that rate would risk a client buffer underflow. Given this, the present system and process includes techniques for determining the most appropriate coding bit rate, from the available rates, in view of the optimum coding bit rate identified by the client. It is noted that the available rates could be provided to the client from the server in a preamble to the streaming media data. In such a case, the client itself would perform the analysis and request the resulting supported coding bit rate from the server. However, in an alternate embodiment, the client would request the optimum coding bit rate it identified, and the server would perform the analysis to determine which supported rate is most appropriate. The server would then provide a data stream exhibiting the selected coding bit rate. In either case, the analysis involves finding a supported coding bit rate that is equal to, or if none are equal, the closest smaller rate to, the optimum coding bit rate identified by the client. Whenever the supported coding bit rate found is lower than the coding bit rate associated with the last generated frame of the streaming media data, all future frames (or those beginning with a frame specified by the client) are generated at that supported rate. However, when the supported coding bit rate found is higher than the coding bit rate associated with the last generated frame, it is determined if a difference between the upper bound gap associated with the last generated frame had it been encoded at the supported coding bit rate found and the upper bound gap associated with that frame encoded at the current coding bit rate, is less than or equal to a maximum allowable difference value. If the difference is less than the maximum allowable difference value, the affected future frames are generated at the supported rate found. But, if the difference is not less than the maximum allowable difference value, the next lower supported coding bit rate is found and the foregoing actions are repeated to ultimately identify the appropriate rate.

[0028] The maximum allowable difference value is computed by the client, and if the server is doing the analysis, the client provides the value along with the request for data at the new coding bit rate. The client chooses the maximum allowable difference value such that the latest anticipated arrival time associated with a frame provided by the server immediately prior to a frame under consideration by the client, had it been coded at the requested coding bit rate, is no more than a prescribed fraction of the way from that frame's target arrival time to its playback deadline (e.g., 1/3 of the way).

[0029] In addition to the just described benefits, other advantages of the present invention will become apparent from

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the detailed description which follows hereinafter when taken in conjunction with the drawing Fig.s which accompany it.

DESCRIPTION OF THE DRAWINGS

[0030] The specific features, aspects, and advantages of the present invention will become better understood with regard to the following description, appended claims, and accompanying drawings where:

FIG. 1 is a diagram depicting a general purpose computing device constituting an exemplary system for implementing the present invention.

FIG. 2 is block diagram of a simplified streaming media communication pipeline.

FIG. 3 is a graph showing schedules at which bits in the coded bit stream pass points A, B, C and D in the communication pipeline of Fig. 2 in terms of bits vs. media time.

FIG. 4 is a graph showing a buffer tube containing a coding schedule in terms of bits vs. media time.

FIG. 5 is a graph showing an arrival schedule and its upper bound in client time vs. media time, where the upper bound is controlled to a target schedule that is increasingly in advance of the playback deadline to provide greater robustness over time.

FIG. 6 is a graph showing a target arrival schedule design.

FIGS. 7(a)-(b) are graphs showing two different target arrival schedules. Fig. 7(a) shows a logarithmic schedule and Fig. 7(b) shows a two-piece linear schedule.

FIG. 8 is a graph showing buffer tubes for various transmission rates.

FIG. 9 is a graph illustrating exponential averaging.

FIG. 10 is a graph showing buffer tube changes and control target adjustments.

FIGS. 11A-C show a flow chart diagramming an embodiment of the coding bit rate control process according to the present invention.

FIG. 12 is a timeline illustrating the conservative limit used in the conservative coding bit rate up-switching procedure.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0031] In the following description of the preferred embodiments of the present invention, reference is made to the accompanying drawings which form a part hereof, and in which is shown by way of illustration specific embodiments in which the invention may be practiced. It is understood that other embodiments may be utilized and structural changes may be made without departing from the scope of the present invention.

I. The Computing Environment

[0032] Before providing a description of the preferred embodiments of the present invention, a brief, general description of a suitable computing environment in which portions of the invention may be implemented will be described. Fig. 1 illustrates an example of a suitable computing system environment 100. The computing system environment 100 is only one example of a suitable computing environment and is not intended to suggest any limitation as to the scope of use or functionality of the invention. Neither should the computing environment 100 be interpreted as having any dependency or requirement relating to any one or combination of components illustrated in the exemplary operating environment 100.

[0033] The invention is operational with numerous other general purpose or special purpose computing system environments or configurations. Examples of well known computing systems, environments, and/or configurations that may be suitable for use with the invention include, but are not limited to, personal computers, server computers, hand-held or laptop devices, multiprocessor systems, microprocessor-based systems, set top boxes, programmable consumer electronics, network PCs, minicomputers, mainframe computers, distributed computing environments that include any of the above systems or devices, and the like.

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[0034] The invention may be described in the general context of computer-executable instructions, such as program modules, being executed by a computer. Generally, program modules include routines, programs, objects, components, data structures, etc. that perform particular tasks or implement particular abstract data types. The invention may also be practiced in distributed computing environments where tasks are performed by remote processing devices that are linked through a communications network. In a distributed computing environment, program modules may be located in both local and remote computer storage media including memory storage devices.

[0035] With reference to Fig. 1, an exemplary system for implementing the invention includes a general purpose computing device in the form of a computer 110. Components of computer 110 may include, but are not limited to, a processing unit 120, a system memory 130, and a system bus 121 that couples various system components including the system memory to the processing unit 120. The system bus 121 may be any of several types of bus structures including a memory bus or memory controller, a peripheral bus, and a local bus using any of a variety of bus architectures. By way of example, and not limitation, such architectures include Industry Standard Architecture (ISA) bus, Micro Channel Architecture (MCA) bus, Enhanced ISA (EISA) bus, Video Electronics Standards Association (VESA) local bus, and Peripheral Component Interconnect (PCI) bus also known as Mezzanine bus.

[0036] Computer 110 typically includes a variety of computer readable media. Computer readable media can be any available media that can be accessed by computer 110 and includes both volatile and nonvolatile media, removable and non-removable media. By way of example, and not limitation, computer readable media may comprise computer storage media and communication media. Computer storage media includes both volatile and nonvolatile, removable and non-removable media implemented in any method or technology for storage of information such as computer readable instructions, data structures, program modules or other data. Computer storage media includes, but is not limited to, RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical disk storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store the desired information and which can be accessed by computer 110. Communication media typically embodies computer readable instructions, data structures, program modules or other data in a modulated data signal such as a carrier wave or other transport mechanism and includes any information delivery media. The term "modulated data signal" means a signal that has one or more of its characteristics set or changed in such a manner as to encode information in the signal. By way of example, and not limitation, communication media includes wired media such as a wired network or direct-wired connection, and wireless media such as acoustic, RF, infrared and other wireless media. Combinations of the any of the above should also be included within the scope of computer readable media.

[0037] The system memory 130 includes computer storage media in the form of volatile and/or nonvolatile memory such as read only memory (ROM) 131 and random access memory (RAM) 132. A basic input/output system 133 (BIOS), containing the basic routines that help to transfer information between elements within computer 110, such as during start-up, is typically stored in ROM 131. RAM 132 typically contains data and/or program modules that are immediately accessible to and/or presently being operated on by processing unit 120. By way of example, and not limitation, Fig. 1 illustrates operating system 134, application programs 135, other program modules 136, and program data 137.

[0038] The computer 110 may also include other removable/non-removable, volatile/nonvolatile computer storage media. By way of example only, Fig. 1 illustrates a hard disk drive 141 that reads from or writes to non-removable, nonvolatile magnetic media, a magnetic disk drive 151 that reads from or writes to a removable, nonvolatile magnetic disk 152, and an optical disk drive 155 that reads from or writes to a removable, nonvolatile optical disk 156 such as a CD ROM or other optical media. Other removable/non-removable, volatile/nonvolatile computer storage media that can be used in the exemplary operating environment include, but are not limited to, magnetic tape cassettes, flash memory cards, digital versatile disks, digital video tape, solid state RAM, solid state ROM, and the like. The hard disk drive 141 is typically connected to the system bus 121 through a non-removable memory interface such as interface 140, and magnetic disk drive 151 and optical disk drive 155 are typically connected to the system bus 121 by a removable memory interface, such as interface 150.

[0039] The drives and their associated computer storage media discussed above and illustrated in Fig. 1, provide storage of computer readable instructions, data structures, program modules and other data for the computer 110. In Fig. 1, for example, hard disk drive 141 is illustrated as storing operating system 144, application programs 145, other program modules 146, and program data 147. Note that these components can either be the same as or different from operating system 134, application programs 135, other program modules 136, and program data 137. Operating system 144, application programs 145, other program modules 146, and program data 147 are given different numbers here to illustrate that, at a minimum, they are different copies. A user may enter commands and information into the computer 110 through input devices such as a keyboard 162 and pointing device 161, commonly referred to as a mouse, trackball or touch pad. Other input devices (not shown) may include a microphone, joystick, game pad, satellite dish, scanner, or the like. These and other input devices are often connected to the processing unit 120 through a user input interface 160 that is coupled to the system bus 121, but may be connected by other interface and bus structures, such as a parallel port, game port or a universal serial bus (USB). A monitor 191 or other type of display device is also connected to the

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system bus 121 via an interface, such as a video interface 190. In addition to the monitor, computers may also include other peripheral output devices such as speakers 197 and printer 196, which may be connected through an output peripheral interface 195. A camera 192 (such as a digital/electronic still or video camera, or film/photographic scanner) capable of capturing a sequence of images 193 can also be included as an input device to the personal computer 110. Further, while just one camera is depicted, multiple cameras could be included as input devices to the personal computer 110. The images 193 from the one or more cameras are input into the computer 110 via an appropriate camera interface 194. This interface 194 is connected to the system bus 121, thereby allowing the images to be routed to and stored in the RAM 132, or one of the other data storage devices associated with the computer 110. However, it is noted that image data can be input into the computer 110 from any of the aforementioned computer-readable media as well, without requiring the use of the camera 192.

[0040] The computer 110 may operate in a networked environment using logical connections to one or more remote computers, such as a remote computer 180. The remote computer 180 may be a personal computer, a server, a router, a network PC, a peer device or other common network node, and typically includes many or all of the elements described above relative to the computer 110, although only a memory storage device 181 has been illustrated in Fig. 1. The logical connections depicted in Fig. 1 include a local area network (LAN) 171 and a wide area network (WAN) 173, but may also include other networks. Such networking environments are commonplace in offices, enterprise-wide computer networks, intranets and the Internet.

[0041] When used in a LAN networking environment, the computer 110 is connected to the LAN 171 through a network interface or adapter 170. When used in a WAN networking environment, the computer 110 typically includes a modem 172 or other means for establishing communications over the WAN 173, such as the Internet. The modem 172, which may be internal or external, may be connected to the system bus 121 via the user input interface 160, or other appropriate mechanism. In a networked environment, program modules depicted relative to the computer 110, or portions thereof, may be stored in the remote memory storage device. By way of example, and not limitation, Fig. 1 illustrates remote application programs 185 as residing on memory device 181. It will be appreciated that the network connections shown are exemplary and other means of establishing a communications link between the computers may be used.

[0042] The exemplary operating environment having now been discussed, the remaining parts of this description section will be devoted to a description of the program modules embodying the invention.

II. Problem Formulation

A. Temporal Coordinate Systems

[0043] It will pay to distinguish between the temporal coordinate systems, or clocks, used to express time. Herein, *media time* refers to the clock running on the device used to capture and timestamp the original content, while *client time* refers to the clock running on the client used to play back the content. It is assumed that media time is real time (i.e., one second of media time elapses in one second of real time) at the time of media capture, while client time is real time at the time of media playback. The symbol τ is used to express media time and the symbol t to express client time, with subscripts and other arguments to indicate corresponding events. For example, $\tau_d(0),\tau_d(1),\tau_d(2),...$ is used to express the playback deadlines of frames 0,1,2,... in media time, while $t_d(0),t_d(1),t_d(2),..$ is used to express the playback deadlines of frames 0,1,2,... at the client. Content may be played back at a rate v times real time. Thus the conversion from media time to client time can be expressed as

$$t = t_0 + \frac{\tau - \tau_0}{v}, \qquad (1)$$

where t_0 and τ_0 represent the time of a common initial event, such as the playback of frame 0 (or the playback of the first frame after a seek or rebuffering event) in media and client coordinate systems, respectively.

B. Leaky Bucket Model

[0044] For the moment imagine a scenario in which both the encoder 200 and the decoder 202 run in real time over an isochronous communication channel of a network 204. In this case, to match the instantaneous coding bit rate to the instantaneous channel rate, an *encoder buffer* 206 is required between the encoder 200 and the network 204 and a *decoder buffer* 208 is required between the network 204 and the decoder 202 , as illustrated in Fig. 2. A *schedule* is the sequence of times at which successive bits in the coded bit stream pass a given point in the communication pipeline.

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The graph in Fig. 3 illustrates the schedules of bits passing the points A, B, C, and D in Fig. 2. Schedule A is the schedule at which captured frames are instantaneously encoded and put into the encoder buffer. This schedule is a staircase in which the nth step rises by $b(n)$ bits at time $\tau(n)$, where $\tau(n)$ is the time at which frame n is encoded, and $b(n)$ is the number of bits in the resulting encoding. Schedules B and C are the schedules at which bits respectively enter and leave the communication channel. The slope of these schedules is R bits per second, where R is the communication rate of the channel. Schedule D is the schedule at which frames are removed from the decoder buffer and instantaneously decoded for presentation. Note that Schedule D is simply a shift of Schedule A. Note also that Schedule B is a lower bound to Schedule A, while Schedule C is an upper bound to Schedule D. Indeed, the gap between Schedules A and B represents, at any point in time, the size in bits of the encoder buffer, while the gap between Schedules C and D likewise represents the size of the decoder buffer. The encoder and decoder buffer sizes are complementary. Thus the coding schedule (either A or D) can be contained within a *buffer tube,* as illustrated in the graph of Fig. 4, having slope R , height B , and initial offset F^d from the top of the tube (or equivalently initial offset $F^e = B - F^d$ from the bottom of the tube). It can be seen that $D = F^d/R$ is the *startup delay* between the time that the first bit arrives at the receiver and the first frame is decoded. Thus it is of interest to minimize F^d for a given R.

[0045] A *leaky bucket* is a metaphor for the encoder buffer. The encoder dumps $b(n)$ bits into the leaky bucket at time $\tau(n)$, and the bits leak out at rate R. In general it is possible for the leak rate R to be high enough so that the bucket occasionally empties. Thus the encoder buffer fullness $F^e(n)$ immediately before frame n is added to the bucket and the encoder buffer fullness $B^e(n)$ immediately after frame n is added to the bucket evolve from an initial encoder buffer fullness $F^e(0) = F^e$ according to the dynamical system

$$B^e(n) = F^e(n) + b(n), \tag{2}$$

$$F^e(n+1) = \max\{0, B^e(n) - R/f(n)\}, \tag{3}$$

where

$$f(n) = \frac{1}{\tau(n+1) - \tau(n)} \tag{4}$$

is the instantaneous frame rate, for n=0,1,2,... If R is sufficiently low, then the bucket will never run dry (underflow), but if R is too low the bucket will eventually overflow. The largest R such that the buffer will never run dry is taken to be the average coding bit rate r_c of the bit stream. This is made more precise in the following two paragraphs.

[0046] A leaky bucket with size B, rate R, and initial fullness F^e is said to *contain* a stream having a schedule characterized by the steps $\{(b(n),\tau(n))\}$ if $B^e(n) \le B$ for all n. The minimum bucket size needed to contain the stream given leak rate R and initial fullness F^e is defined as

$$B^e_{\min}(R, F^e) = \min_n B^e(n), \tag{5}$$

while the corresponding initial decoder buffer fullness is defined as

$$F^d_{\min}(R, F^e) = B^e_{\min}(R, F^e) - F^e. \tag{6}$$

The minimum of each of these over F^e is denoted as

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$$B^e_{\min}(R) = \min_{F^e} B^e_{\min}(R, F^e), \tag{7}$$

$$F^d_{\min}(R) = \min_{F^e} F^d_{\min}(R, F^e). \tag{8}$$

It is shown in [10, Proposition 2] that remarkably; these are each minimized by the same value of F^e, which is hence equal to

$$F^e_{\min}(R) = B^e_{\min}(R) - F^d_{\min}(R). \tag{9}$$

Thus the bit stream with schedule $\{(b(n),\tau(n))\}$, for each bit rate R there is a unique leaky bucket that contains the stream and that has the minimum buffer size B as well as the minimum startup delay $D = F^d/R$. These parameters can be computed with the above equations.

[0047] For sufficiently low leak rates R, the leaky bucket does not underflow, when beginning with initial fullness $F^e = F^e_{\min}(R)$. Tthe maximum such rate R may be used as the average coding bit rate r_c of a bit stream with coding schedule $\{(b(n),\tau(n))\}$.

[0048] Leak rates R greater than r_c can also be employed. It is shown in [10] that both $B^e_{\min}(R)$ and $F^d_{\min}(R)$ are decreasing, piecewise linear, and convex in R. Hence if the transmission rate R is greater than the average coding bit rate r_c, the startup delay $D = F^d_{\min}(R)/R$ can be reduced compared to $D = F^d_{\min}(r_c)/R$. This fact will be used in Section IV-A.

[0049] A leaky bucket with leak rate $R=r_c$, size $B = B^e_{\min}(r_c)$ and initial decoder buffer fullness $F^d = F^d_{\min}(r_c)$ thus corresponds to a straight buffer tube bounding the coding schedule as in Fig. 4. Each stream in the media file has a coding schedule; thus each stream corresponds to a straight buffer tube with slope equal to the average coding bit rate r_c of the stream. The size B of the buffer tube and its offset F^e (or F^d) relative to the coding schedule can be either computed by the above formula for a variable bit rate (VBR) stream (such as a constant-quality sub-stream of a scalable stream), or obtained from the size B and initial state F^e of the actual encoder buffer used to encode the stream if it is a constant bit rate (CBR) stream.

[0050] In the following the gap $g(n)$ at frame n between the buffer tube *upper bound* and the coding schedule is considered, as depicted in Fig. 4. Note that the decoder buffer fullness $F^d(n) = B - F^e(n)$ can also be expressed

$$F^d(n) = b(n) + g(n) = g(n-1) + \frac{r_c(n)}{f(n)}, \tag{10}$$

where $r_c(n)$ is the coding bit rate of the buffer tube, now taking into account that different frames may lie in different buffer tubes with different coding bit rates as coding bit rate control is applied and streams are switched.

C. Rate Control Model

[0051] Assume for the moment that bits arrive at the client at a constant rate r_a. Then frame n (having size $b(n)$) arrives at the client $b(n)/r_a$ seconds after frame n-1. Indeed, the index of a bit is proportional to its arrival time. Dividing the vertical scale of the schedules in Fig. 4 by r_a, the schedules are obtained in terms of client time, rather than bits, as shown in the graph of Fig. 5. The coding schedule divided by r_a becomes the *arrival schedule,* which provides for each n the time $t_a(n)$ of arrival of frame n at the client. The buffer tube upper bound (in bits) divided by r_a becomes the buffer tube upper bound (in time), which provides for each n the time $t_b(n)$ by which frame n is guaranteed to arrive. In the

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same plot the *playback deadline* is shown, which is the time $t_d(n)$ at which frame n is scheduled to be played (after instantaneous decoding). Thus the gap between a frame's arrival time and its playback deadline is the client buffer duration at the time of the frame arrival. This must be non-negative to allow continuous playback.

[0052] In reality the arrival rate is not constant. If $t_a(n\text{-}1)$ and $t_a(n)$ are the arrival times of frames n and n-1 respectively, then

$$r_a(n) = \frac{b(n)}{t_a(n) - t_a(n-1)} \tag{11}$$

can be defined as the *instantaneous arrival rate* at frame n. In practice the average arrival rate at frame n is estimated by a moving average $\tilde{r}_a(n)$ of previous values of $r_a(n)$, as detailed in Section IV-C. Hence using Eq. (11) the arrival time of frame n can be expressed in terms of the arrival time of frame n-1 as

$$t_a(n) = t_a(n-1) + \frac{b(n)}{r_a(n)} \tag{12}$$

$$= t_a(n-1) + \frac{b(n)}{\tilde{r}_a(n)} + v(n), \tag{13}$$

where the $v(n)$ term is an error term that captures the effect of using the slowly moving average $\tilde{r}_a(n)$. From Eq. (10), however, it can be seen that

$$b(n) = \frac{r_c(n)}{f(n)} + g(n-1) - g(n), \tag{14}$$

whence (substituting Eq. (14) into Eq. (13)) yields

$$t_a(n) = t_a(n-1) + \frac{r_c(n)}{f(n)\tilde{r}_a(n)} + \frac{g(n-1)}{\tilde{r}_a(n)} - \frac{g(n)}{\tilde{r}_a(n)} + v(n). \tag{15}$$

Now defining the buffer tube upper bound (in time) of frame n as

$$t_b(n) = t_a(n) + \frac{g(n)}{\tilde{r}_a(n)}, \tag{16}$$

so that

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$$t_b(n) - t_b(n-1) = t_a(n) - t_a(n-1) + \frac{g(n)}{\tilde{r}_a(n)} - \frac{g(n-1)}{\tilde{r}_a(n-1)}, \qquad (17)$$

the following update equation is obtained:

$$t_b(n) = t_b(n-1) + \frac{r_c(n)}{f(n)\tilde{r}_a(n)} + w(n-1), \qquad (18)$$

where

$$w(n-1) = \frac{g(n-1)}{\tilde{r}_a(n)} - \frac{g(n-1)}{\tilde{r}_a(n-1)} + v(n). \qquad (19)$$

is again an error term that captures variations around a locally constant arrival rate.

[0053] Using Eq. (16), the client can compute $t_b(n\text{-}1)$ from the measured arrival time $t_a(n - 1)$, the estimated arrival rate $\tilde{r}_a(n - 1)$, and $g(n - 1)$ (which can be transmitted to the client along with the data in frame n-1 or computed at the client as described in Section V-E). Then using Eq. (18), the client can control the coding bit rate $r_c(n)$ so that $t_b(n)$ reaches a desired value, assuming the frame rate and arrival rate remain roughly constant. From this perspective, Eq. (18) can be regarded as the state transition equation of a feedback control system and it is thus possible to use a control-theoretic approach to regulate the coding bit rate.

D. Control Objective

[0054] With the state transition equation defined in Eq. (18), uninterrupted playback can be achieved by regulating the coding bit rate so that the client buffer does not underflow. To introduce a margin of safety that increases over time, a *target schedule* is introduced, as illustrated in Fig. 5, whose distance from the playback deadline grows slowly over time. By regulating the coding bit rate, it is attempted to control the buffer tube upper bound so that it tracks the target schedule. If the buffer tube upper bound is close to the target schedule, then the arrival times of all frames will certainly be earlier than their playback deadlines and thus uninterrupted playback will be ensured. Note that controlling the actual arrival times (rather than their upper bounds) to the target would result in an approximately constant number of bits per frame, which would in turn result in very poor quality overall. By taking the leaky bucket model into account, it is possible to establish a control that allows the instantaneous coding bit rate to fluctuate naturally according to the encoding complexity of the content, within previously established bounds for a given average coding bit rate.

[0055] Although controlling the upper bound to the target schedule is our primary goal, it is also desirable to minimize quality variations due to large or frequent changes to the coding bit rate. This can be achieved by introducing into the cost function a penalty for relative coding bit rate differences.

[0056] Letting $t_T(n)$ denote the target for frame n, the following cost function is used to reflect both of concerns:

$$I = \sum_{n=0}^{N} \left((t_b(n) - t_T(n))^2 + \sigma \left(\frac{r_c(n+1) - r_c(n)}{\tilde{r}_a(n)} \right)^2 \right), \qquad (20)$$

where the first term penalizes the deviation of the buffer tube upper bound from the target schedule and the second term penalizes the relative coding bit rate difference between successive frames. N is the control window size and σ is a Lagrange multiplier or weighting parameter to balance the two terms.

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III. Optimal Control Solution

[0057] Before presenting the optimal control solution, the design rational of the target schedule will be described.

A. Target Schedule Design

[0058] Fig. 6 is a graph showing an illustrative target schedule. The gap between the playback deadline and the target schedule is the desired client buffer duration (in client time). If the gap is small at the beginning of streaming, then it allows a small startup delay, while if the gap grows slowly over time, it gradually increases the receiver's ability to counter jitter, delays, and throughput changes.

[0059] The slope of the target schedule relates the average coding bit rate to the average arrival rate. Let $t_T(n)$ be the target for frame n. As illustrated in Fig. 6, the slope of the target schedule at frame n is

$$s(n) = \frac{t_T(n+1) - t_T(n)}{\tau(n+1) - \tau(n)}. \qquad (21)$$

If the upper bound $t_b(n)$ aligns perfectly with the target schedule (i.e., $t_b(n) = t_T(n)$) and the arrival rate r_a is constant (i.e., the $w(n\text{-}1)$ term vanishes), from Eq. (18),

$$s(n) = \frac{t_b(n+1) - t_b(n)}{\tau(n+1) - \tau(n)} = \frac{r_c(n)}{r_a}. \qquad (22)$$

Thus initially, when the slope was low, i.e., less than $1/v$, r_a/r_c is greater than v and more than v seconds of content are received per second of client time, causing the client buffer (which is playing out only v seconds of content per second of client time) to grow. Over time, as the slope approaches $1/v$, r_a/r_c approaches v and the buffer remains relatively constant (except for changes due to variations in the instantaneous coding bit rate), since content is received and played back at the same speed v. Next two target schedule functions are presented that illustrate the general design idea.

1) Logarithmic Target Schedule

[0060] One way to choose the target schedule t_T is to have the client buffer duration grow logarithmically over time. Specifically, if t_d is the playback deadline, then for each t_d greater than some start time t_{d0},

$$t_T = t_d - \frac{b}{a}\ln(a(t_d - t_{d0}) + 1). \qquad (23)$$

Since by Eq. (1), $t_d = t_{d0} + (\tau_d - \tau_{d0})/v$ this yields

$$s = \frac{dt_T}{d\tau_d} = \frac{dt_T dt_d}{dt_d d\tau_d} = \frac{1}{v} - \frac{b}{a(\tau_d - \tau_{d0}) + v}, \qquad (24)$$

and hence the initial slope at frame 0 (when $t_d = t_{d0}$) is $s(0) = (1\text{-}b)/v$. Setting b=0.5 implies that initially r_c/r_a=0.5/v, causing the client buffer to grow initially at two times real time. Further setting a=0.15 implies that the client buffer duration will be 7.68 seconds after 1 minute, 15.04 seconds after 10 minutes, and 22.68 seconds after 100 minutes, regardless of v.

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2) Two-piece Linear Target Schedule

[0061] Another way to choose the target schedule t_T is to have the client buffer duration grow linearly at rate b seconds of media time per second of client time until the buffer duration reaches a seconds of media time, after which it remains constant. Specifically, for each t_d greater than some start time t_{d0},

$$t_T = \begin{cases} t_d - b(t_d - t_{d0}) & t_d \le t_{d0} + a/b \\ t_d - a & t_d \ge t_{d0} + a/b \end{cases} \quad (25)$$

The initial slope is again $s(0)=(1-b)/v$. Setting b=0.5 implies that initially r_c/r_a = 05/v , causing the client buffer to grow initially at two times real time. Further setting a = 10 implies that the client buffer duration will reach 10 seconds of media time after 20 seconds of client time, regardless of v.

[0062] Figs. 7(a) and (b) show graphs of the above two target schedules. As one can see, if a client buffer duration of 10 seconds is considered to be a safe level against jitter, delay and network fluctuations, then the two-piece linear target schedule reaches the safe level in 20 seconds, much faster than the logarithmic target schedule. On the other hand, the slope of the two-piece linear target schedule remains lower for longer (hence the coding bit rate and quality are lower for longer) and furthermore experiences an abrupt change at 20 seconds when its slope changes from 0.5/v to 1/v. Consequently, the coding bit rate will not change as smoothly as with the logarithmic target schedule, although it will not be as abrupt as the schedule itself because of the smoothness objective in the controller design.

B. Optimal Controller Design

[0063] Recall from Eq. (18) the fundamental state transition equation, which describes the evolution of the buffer tube upper bound $t_b(n)$ in terms of the coding bit rate $r_c(n)$:

$$t_b(n+1) = t_b(n) + \frac{r_c(n+1)}{f\tilde{r}_a} + w(n). \quad (26)$$

Here it is now assumed that the frame rate f and the average arrival rate $\tilde{r}_a$ are relatively constant. Deviations from this assumption are captured by $w(n)$.

[0064] It is desired to control the upper bound by adjusting the coding bit rate. As each frame arrives at the client, a feedback loop can send a message to the server to adjust the coding bit rate. Note, however, that by the time frame n arrives completely at the client, frame $n+1$ has already started streaming from the server. Thus the coding bit rate $r_c(n+1)$ for frame $n+1$ must already be determined by time $t_a(n)$. Indeed, at time $t_a(n)$, frame n+2 is the earliest frame for which the controller can determine the coding bit rate. Hence at time $t_a(n)$, the controller's job must be to choose $r_c(n+2)$. This one-frame delay in the feedback loop must be explicitly accounted for.

[0065] For simplicity, the target schedule is linearized around the time that frame n arrives. The linearization is equivalent to using a line tangent to the original target schedule at a particular point as an approximate target schedule. Thus,

$$t_T(n+1) - 2t_T(n) + t_T(n-1) = 0. \quad (27)$$

Rather than directly control the evolution of the upper bound, which grows without bound, for the purposes of stability an error space formulation is used. Defining the error as

$$e(n) = t_b(n) - t_T(n), \quad (28)$$

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results in

$$e(n+1)-e(n) = (t_b(n+1)-t_T(n+1))-(t_b(n)-t_T(n)) \quad (29)$$

$$= (t_b(n+1)-t_b(n))-(t_T(n+1)-t_T(n)) \quad (30)$$

$$= \frac{r_c(n+1)}{f\tilde{r}_a}-(t_T(n+1)-t_T(n))+w(n), \quad (31)$$

from which in turn

$$\begin{aligned}&(e(n+1)-e(n))-(e(n)-e(n-1))\\ &=[r_c(n+1)-r_c(n)]/f\tilde{r}_a\\ &\quad-(t_T(n+1)-2t_T(n)+t_T(n-1))\\ &\quad+(w(n)-w(n-1))\end{aligned} \quad (32)$$

$$= \frac{r_c(n+1)-r_c(n)}{f\tilde{r}_a}+(w(n)-w(n-1)) \quad (33)$$

The control input is then defined as

$$u(n)=\frac{r_c(n+2)-\hat{r}_c(n+1)}{\tilde{r}_a}, \quad (34)$$

where $\hat{r}_c(n+1)$ is a possibly quantized version of $r_c(n+1)$ (as defined in Section IV-D) and the disturbance is defined as

$$d(n)=\frac{\hat{r}_c(n)-r_c(n)}{f\tilde{r}_a}+w(n)-w(n-1). \quad (35)$$

Then Eq. (33) can be rewritten

$$e(n+1)=2e(n)-e(n-1)+\frac{u(n-1)}{f}+d(n). \quad (36)$$

Therefore , defining the error vector

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$$\mathbf{e}(n) = \begin{bmatrix} e(n) \\ e(n-1) \\ u(n-1) \end{bmatrix} = \begin{bmatrix} t_b(n) \\ t_b(n-1) \\ \dfrac{r_c(n+1)}{\tilde{r}_a} \end{bmatrix} - \begin{bmatrix} t_T(n) \\ t_T(n-1) \\ \dfrac{\hat{r}_c(n)}{\tilde{r}_a} \end{bmatrix} \qquad (37)$$

the error space representation of the system can be expressed as

$$\mathbf{e}(n+1) = \begin{bmatrix} 2 & -1 & \dfrac{1}{f} \\ 1 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \mathbf{e}(n) + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u(n) + \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} d(n), \qquad (38)$$

or $e(n+1) = \Phi e(n) + \Gamma u(n) + \Gamma_d d(n)$ for appropriate matrices Φ, Γ and Γ_d.

[0066] Assuming the disturbance *d(n)* is a pure white noise, and assuming *perfect state measurement* (i.e., all components of *e*(*n*) can be measured without using an estimator), the disturbance *d*(*n*) does *not* affect the controller design. Thus a linear controller represented by

$$u(n) = -G\mathbf{e}(n) \qquad (39)$$

can be used where G is a *feedback gain.* By the time frame *n* is completely received, all elements of **e**(*n*) are available at the client and *u*(*n*) can thus be computed. The ideal coding bit rate for frame *n* + 2 can then be computed as

$$r_c(n+2) = \hat{r}_c(n+1) - G\mathbf{e}(n)\tilde{r}_a. \qquad (40)$$

Finding the optimal linear controller amounts to finding the feedback gain *G** that minimizes the quadratic cost function defined in Section II-D. Before continuing with the design, the system *controllability matrix C*,

$$C = \begin{bmatrix} \Gamma & \Phi\Gamma & \Phi^2\Gamma \end{bmatrix} = \begin{bmatrix} 0 & \dfrac{1}{f} & \dfrac{2}{f} \\ 0 & 0 & \dfrac{1}{f} \\ 1 & 0 & 0 \end{bmatrix} \qquad (41)$$

will be checked first which has full rank for any frame rate *f*. Thus, the system is *completely controllable* and the state e(*n*) can be regulated to any desirable value. Now recall that the cost function defined in Section II-D is

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$$I = \sum_{n=0}^{N} \left\{ (t_b(n) - t_T(n))^2 + \sigma \left(\frac{r_c(n+1) - r_c(n)}{\tilde{r}_a} \right)^2 \right\} \qquad (42)$$

$$= \sum_{n=0}^{N} \{ e(n)^T Q e(n) + u(n-1)^T R u(n-1) \}, \qquad (43)$$

where $Q = C^T C$ (with C = [1 0 0]) and R = σ. Then, the original control problem of tracking the target schedule while smoothing the coding bit rate fluctuations (i.e., minimizing the cost function I) is converted to a standard regulator problem in the error space. Letting $N \to \infty$, the infinite horizon optimal control problem can be solved by applying the results in [11, Section 3.3] to obtain an optimal regulator in two steps: 1) solving, to get S, the *discrete algebraic Riccati equation* (DARE)

$$S = \Phi^T \{ S - S\Gamma [\Gamma^T S \Gamma + R]^{-1} \Gamma S \} \Phi + Q, \qquad (44)$$

and 2) computing the optimal feedback gain

$$G^* = [\Gamma^T S \Gamma + R]^{-1} \Gamma^T S \Phi. \qquad (45)$$

The existence and uniqueness of S (and in turn of G^*) is guaranteed when Q is nonnegative definite and R is positive definite, which is straightforward to verify in this case.

C. Frame Rate

[0067] In the previous section, it was assumed that the frame rate is constant. This assumption is reasonable when streaming a single medium, such as video without audio. Variable frame rate video is usually achieved by skipping frames, which can be accommodated by setting $b(n) = 0$. However, usually video and audio are streamed together, and their merged coding schedule may have no fixed frame rate. Even if there is a fixed frame rate f, it may be desirable to operate the controller at a rate lower than f, to reduce the feedback rate, for example.

[0068] To address these issues, in practice the notion of a *virtual frame rate* is used. A virtual frame rate f is chosen, for example f =1 frame per second (fps); media time is partitioned into intervals of size $1/f$; and all of the (audio and video) frames arriving within each interval are modeled as a *virtual frame* whose decoding and playback deadline is the end of the interval.

[0069] This approach has several advantages. First, it allows offline design of a universal feedback gain, which is independent of the actual frame rate of the stream or streams. Second, it allows the rate of feedback from the client to the server to be reduced. And finally, since the interval between virtual frames is typically safely larger than a round trip time (RTT), a one-frame delay in the error space model (as described in the previous section) is sufficient to model the feedback delay. Otherwise it would be necessary to model the feedback delay with approximately RTT/f additional state variables to represent the network delay using a shift register of length RTT/f.

[0070] In the remainder of this description a virtual frame rate f = 1 fps is employed, and is referred to simply as the frame rate. Likewise, a virtual frame is referred to simply as a frame.

[0071] It is noted that with the present controller design rationale, the deviation of the buffer tube upper bound from the control target can be reduced by decreasing the σ value. A smaller value of σ value implies a relative larger penalty on the deviation term in the cost function and thus forces the upper bound to track the target more closely. This, however, happens at the cost of sacrificing coding bit rate smoothness, since the corresponding term in the cost function will be weighted less. It has been found with σ = 500 that while the buffer tube upper bound deviates only slightly from the control target, the coding bit rate has undesirable oscillations. On the other hand, a large σ value will certainly yield smoother coding bit rates, but might also incur client buffer underflow since the buffer tube upper bound is allowed to

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deviate significantly away from the control target. Therefore, a good choice of σ should take into account this trade-off. In tested embodiments of the present system and process, $\sigma = 4000$ was chosen when the coding bit rate switches up and $\sigma = 2000$ when it switches down. Note that a slightly more aggressive strategy is allowed in the latter case to further reduce the chance of client buffer underflow.

IV. Practical Issues with Streaming

A. Fast Startup

[0072] As discussed in previous sections, the startup delay is the length of the period from the time that content first begins to arrive at the client to the time that playback begins. During this period, content accumulates in the receiver buffer to counter packet jitter, retransmission delay, variations in network bandwidth, and variations in instantaneous coding bit rate. It is conceivable that a longer startup delay would increase the chances of being able to maintain continuous playback in a dynamic network environment. On the other hand, users expect the startup delay to be as small as possible. Thus, it is desirable to investigate techniques that can reduce the startup delay while retaining robustness. One possible approach is to transmit the content at a faster than normal rate at the beginning of streaming. This *bursting* technique will certainly build up the buffer duration in a small amount of time. It, however, puts extra pressure on the network by demanding a higher than normal initial bandwidth, which may not even be available.

[0073] The present system and process employs an alternative *fast startup* technique, which takes advantage of the properties of adaptive media. As discussed in previous sections, by choosing an initial coding bit rate r_c equal to half the arrival rate r_a (divided if necessary by the playback speed v), the client buffer duration can grow at two times real time during playback. Growing the client buffer during playback enables the startup delay to be low, because playback can begin while the buffer duration is still low. Beginning playback while the buffer duration is low is not particularly risky over the short term, because the probability of deep congestion occurring in any short interval is low. However, the probability of deep congestion occurring in a long interval is high, so it is important for the buffer duration to be high over the long term. Without the ability to grow the buffer duration during playback, startup would have to be delayed until the buffer duration was sufficiently high to guarantee continuous playback over the long term.

[0074] Moreover, if the transmission rate is twice the coding bit rate, the startup delay can be further reduced by taking advantage of properties of the leaky bucket model [10]. As detailed in Section II-B, the startup delay for a given bit stream is $D = F^d_{\min}(R)/R$ when the stream is transmitted at rate R. This is ordinarily equal to $F^d_{\min}(r_c)/r_c$ when transmitting the stream at its coding bit rate. However, when transmitting the stream at a rate $r_a > r_c$ ($r_c = 0.5r_a/v$), then the startup delay drops to $F^d_{\min}(r_a)/r_a$. Thus the startup delay D decreases both because the numerator decreases and because the denominator increases.

[0075] The graph in Fig. 8 illustrates the decrease in the initial decoder buffer fullness $F^d_{\min}(R)$ as R changes from r_c to r_a. In particular, it depicts the coding schedule for a given bit stream, as well as upper and lower bounds, denoted Tube I and Tube II, corresponding to two leaky buckets with leak rates r_c and r_a respectively, both containing the coding schedule. Tube II is smaller than Tube I, since the minimum size $B_{\min}(R)$ of a leaky bucket containing a given stream is decreasing in the leak rate R [10]. Likewise, the initial decoder buffer fullness $F_{\min}(R)$ is decreasing in R [10]. Hence the playback deadline for frame 0 can begin as early as client time $t_{0\_II} = F^d_{\min}(r_a)/r_a$, instead of $t_{0\_I} = F^d_{\min}(r_c)/r_a$. From there, the playback deadline advances at $1/v$ seconds of client time per second of media time.

B. Controller Initialization

[0076] As illustrated in Fig. 8, the target schedule starts at the same time as the playback deadline and grows according to a predefined function. The controller attempts to control the upper bound of Tube I to the target schedule. Initially the upper bound of Tube I is above the target schedule (and is indeed above the playback deadline, though it is known that this is safe). Hence, when the playback starts, the controller would try to close the gap by decreasing the coding bit rate. This, however, would not be desirable because the current coding bit rate is already lower than the arrival rate to allow the client buffer to grow. Further reduction of the coding bit rate would not be proper. To avoid this effect, the controller is initialized when the upper bound of Tube I exceeds the target schedule i.e., at point B in Fig. 8. Point B can be found analytically, but in practice there is no need to explicitly solve for it. The controller can be initialized as soon as the upper bound of Tube I exceeds the target.

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C. Exponential Averaging of the Arrival Rate

[0077] Using the average arrival rate (instead of the instantaneous arrival rate) helps to reduce coding bit rate oscillations. This section details a new exponential averaging algorithm for the arrival rate.

[0078] Let $\tilde{r}_a(k)$ and $r(k)$ be the average arrival rate and the instantaneous arrival rate, respectively, when packet k is received. Note that unlike the controlling operation, the rate averaging operation may be performed after the arrival of every *packet,* rather than after the arrival of every *frame.* Hence the discrete packet index k is used rather than the frame index n . Instead of using the widely adopted exponentially weighted moving average (EWMA)

$$\tilde{r}_a(k) = \beta(k)\tilde{r}_a(k-1) + (1-\beta(k))r_a(k) \qquad (46)$$

with constant $\beta(k) = \beta$, the exponential averaging is performed more carefully. In the present algorithm, the factor $\beta(k)$ is not constant, but varies according to the packets' inter-arrival gaps. This new algorithm has several advantages over the EWMA algorithm with constant $\beta(k)$. First, the estimate of the average arrival rate $\tilde{r}_a(k)$ goes to zero naturally as the gap since the last packet goes to infinity, rather than being bounded below by $\beta\tilde{r}_a(k\text{-}1)$. Second, the estimate of the average arrival rate $\tilde{r}_a(k)$ does not go to infinity as the gap since the last packet goes to zero. This is especially important, since packets often arrive in bursts, causing extremely high instantaneous arrival rates. And finally, the estimate of the average arrival rate $\tilde{r}_a(k)$ does not over-weight the initial condition, as if it represented the infinite past. This is especially important in the early stages of estimation.

[0079] As in Eq. (11), the instantaneous arrival rate after packet k is defined as

$$r_a(k) = \frac{b(k)}{t_a(k) - t_a(k-1)}, \qquad (47)$$

where here $b(k)$ denotes the size of packet k and $t_a(k)$ denotes the arrival time of packet k. The discrete time function $r_a(k)$ is extended to the piecewise constant continuous time function $r_a(t)$ by

$$r_a(t) = r_a(k) \quad \text{for all } t \in (t_a(k-1), t_a(k)), \qquad (48)$$

as illustrated in the graph in Fig. 9. Then the function $r_a(t)$ is filtered by the exponential impulse response $\alpha e^{-\alpha t}$, $t \geq 0$, for some time constant $1/\alpha$:

$$\tilde{r}_a(k) = \frac{\int_{t(0)}^{t(k)} r_a(t')\alpha e^{-\alpha(t(k)-t')}dt'}{\int_{t(0)}^{t(k)} \alpha e^{-\alpha(t(k)-t')}dt'}. \qquad (49)$$

(Here and in the remainder of this sub-section the subscript is suppressed from the arrival time $t_a(k)$.) Note that $\int_t^{\infty} \alpha e^{-\alpha t'}dt' = e^{-\alpha t}$, the denominator integral can be expressed as $1 - e^{-\alpha(t(k)-t(0))}$. Now, the range of the numerator integral is split into ranges (t(0), t(k-1)] and (t(k-1),t(k)] to obtain a recursive expression for $\tilde{r}_a(k)$ in terms of $\tilde{r}_a(k\text{-}1)$ and $r_a(k)$,

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$$\tilde{r}_a(k) = \frac{1-e^{-\alpha[t(k-1)-t(0)]}}{1-e^{-\alpha[t(k)-t(0)]}} e^{-\alpha[t(k)-t(k-1)]} \tilde{r}_a(k-1) + \frac{1-e^{-\alpha[t(k)-t(k-1)]}}{1-e^{-\alpha[t(k)-t(0)]}} r_a(k) \tag{50}$$

$$= \beta(k)\tilde{r}_a(k-1) + (1-\beta(k))r_a(k), \tag{51}$$

where

$$\beta(k) = \frac{e^{-\alpha[t(k)-t(k-1)]} - e^{-\alpha[t(k)-t(0)]}}{1-e^{-\alpha[t(k)-t(0)]}}. \tag{52}$$

Note that $\beta(k)$ is numerically stable as k goes to infinity. However, as the gap $\delta = t(k) - t(k\text{-}1)$ goes to zero, $1 - \beta(k)$ goes to zero while $r_a(k)$ goes to infinity. Their product, however, is well behaved. Indeed,

$$\tilde{r}_a(k) = \frac{1-e^{-\alpha[t(k-1)-t(0)]}}{1-e^{-\alpha[\delta+t(k-1)-t(0)]}} e^{-\alpha\delta} \tilde{r}_a(k-1) + \frac{1-e^{-\alpha\delta}}{1-e^{-\alpha[t(k)-t(0)]}} \frac{b(k)}{\delta} \tag{53}$$

$$\rightarrow \tilde{r}_a(k-1) + \frac{\alpha b(k)}{1-e^{-\alpha[t(k)-t(0)]}} \tag{54}$$

as $\delta \rightarrow 0$, using l'Hôpital's rule. Thus Eq. (54) is the update rule in the case when $t(k) = t(k\text{-}1)$.

D. Choosing a Stream Given a Coding bit rate

[0080] When the client requests a coding bit rate $r_c(n)$, the server complies by choosing a stream (or sub-stream of a scalable stream) having coding bit rate $\hat{r}_c(n)$ approximately equal to $r_c(n)$. There are several reasons that $\hat{r}_c(n)$ may differ from $r_c(n)$. The first reason is that there are only a finite number of streams (or sub-streams) in the media file, even if fine grain scalable coding is used. Thus there may be no stream in the media file with average coding bit rate exactly equal to $r_c(n)$. The second reason is that, even if there is a stream in the media file with average coding bit rate exactly equal to $r_c(n)$, the buffer tube for the stream may be too large to allow switching to the stream without risk of client buffer underflow. In fact, whenever the stream switches, there is generally a discontinuity in the upper bound, which may be either positive or negative. A positive shift in the upper bound is illustrated in the graph in Fig. 10, which, if large, could cause the client buffer to underflow either immediately or eventually.

[0081] Thus the server must choose a stream that causes the upper bound to shift up no more than some amount $\Delta^{max}g(n\text{-}1)$ supplied to it by the client. The client supplies $\Delta^{max}g(n\text{-}1)$ to the server in its feedback along with $r_c(n)$, shortly after client time $t_a(n\text{-}2)$ (after frame n-1 has already begun streaming). Upon receiving the feedback, the server selects a stream with coding bit rate $\hat{r}_c(n)$ as high as possible such that $\hat{r}_c(n) \le r_c(n)$ and, if $\hat{r}_c(n) > \hat{r}_c(n\text{-}1)$ (i.e., if it is a switch up in rate), then $g^{new}(n\text{-}1) - g^{old}(n\text{-}1) \le \Delta^{max}g(n\text{-}1)$, where $g^{new}(n\text{-}1)$ and $g^{old}(n\text{-}1)$ are illustrated in Fig. 10. The constraint given by $\Delta^{max}g(n\text{-}1)$ is not applied if it is a switch down in rate.

[0082] The client chooses $\Delta^{max}g(n - 1)$ to limit (its prediction of) what the upper bound would be at time $t_a(n - 1)$ if the new coding bit rate were in effect, namely,

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$$t_b^{new}(n-1) \approx \frac{t_b(n-2)+\hat{r}_c(n-1)}{f\tilde{r}_a}+\frac{\Delta g(n-1)}{\tilde{r}_a} \qquad (55)$$

$$\leq t_T(n-1)+p[t_d(n-1)-t_T(n-1)]. \qquad (56)$$

That is, the client chooses $\Delta^{max}g(n\text{-}1)$ to limit $t_b^{new}(n-1)$ so that it would be no more than fraction p of the way from the target $t_T(n\text{-}1)$ to the playback deadline $t_d(n\text{-}1)$. In tested embodiments of the present system and process, p=1/3 was chosen.

[0083] It is noted that in an alternate embodiment, the information as to what coding bit rates the server supports can be provided to the client ahead of time and the client can be responsible for performing the foregoing analysis. In this case, the client would only request coding bit rates that are supported by the server, and there would be no need to provide the $\Delta^{max}g(n\text{-}1)$ to the server with the request.

E. Control Target Adjustment

[0084] When a frame with a new average coding bit rate $\hat{r}_c(n)$ arrives at the client at time $t_a(n)$, there is a shift in the upper bound. This shift can be on the order of seconds and hence, rather than being negligible, can be confusing to the controller. If the shift is upward, for example, the controller will immediately try to reduce the coding bit rate $r_c(n+2)$. If the shift is downward, on the other hand, the controller will immediately try to increase the coding bit rate $r_c(n+2)$. Either way is probably not good; the intention is that $\hat{r}_c(n)$ will be maintained unless there is a disturbance in the arrival rate. One solution is to introduce a simultaneous shift in the control target schedule equal to $\Delta g(n\text{ - }1)/\tilde{r}_a$; where $\Delta g(n\text{ - }1) = g^{new}(n\text{ - }1) - g^{old}(n\text{-}1)$ is the actual shift in the upper bound (in bits) at frame n-1 computed at the server, as illustrated in Fig. 10. The server can send this value to the client along with frame n. If there is no stream change, this value is simply zero.

[0085] If the control target schedule is adjusted whenever the coding bit rate changes, it will no longer follow the designed target schedule. The adjusted target schedule will be referred to as the *control target* schedule to distinguish it from the *designed target* schedule (or simply the *target schedule).*

[0086] The control target schedule, of course, should have a tendency to approach the designed target schedule. The basic idea is to decrease the slope of the control target schedule when it is above the designed target schedule and to increase the slope when it is below.

[0087] For the logarithmic target schedule $t_T = t_d - \frac{b}{a}\ln(at_d+1)$ (where $t_d = t_{d0} + (\tau_d - \tau_{d0})/v$), according to Eq. (24) the slope at media time τ_d is

$$s = \frac{dt_T}{d\tau_d} = \frac{1}{v} - \frac{b}{a(\tau_d-\tau_{d0})+v}. \qquad (57)$$

If d is defined as the distance between the playback deadline and the target schedule, namely

$$d = \frac{b}{a}\ln\left(a\left(\frac{\tau_d-\tau_{d0}}{v}\right)+1\right), \qquad (58)$$

then the slope may be expressed as a function of d

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$$s = \frac{1}{\nu} - \frac{b}{\nu e^{(a/b)d}}. \qquad (59)$$

Hence whenever d is the distance between the playback deadline and the control target, the slope of the control target is set to s in Eq. (59). Specifically, if $t_T^A(n)$ is the control target at frame n after the shift, then $t_T^A(n\text{-}1)$ is reset to be $t_T^A(n)\text{-}s/f$. Then $t_T^A(n)$ and $t_T^A(n\text{-}1)$ is used in place of $t_T(n)$ and $t_T(n\text{-}1)$ to compute the error vector $e(n)$ in Eq. (37). The resulting error vector is then used to compute the ideal coding bit rate in Eq. (40).

[0088] For the two-piece linear target schedule, the slope is easy to compute by using a predefined time period over which the control target schedule is expected to return to the target schedule. The slope of the control target schedule can then be computed from the distance d and the period. In tested embodiments of the present system and process the period was set to 50 seconds.

V. Implementation Details

[0089] This section highlights implementation details on both the sender and the receiver side.

A. Generation of Virtual Streams

[0090] In tested embodiments of the present a system and process, a fine grained scalable (FGS) stream comprises a set of data units, each tagged by a Lagrange multiplier λ representing the per-bit decrease in distortion if the data unit is received by the client. If the λ for the data unit is above a threshold, then the data unit is included in a virtual stream corresponding to that threshold. Each threshold corresponds to an overall number of bits and hence an average coding bit rate for the virtual stream. In tested embodiments, $N = 50$ virtual streams are generated. A threshold is chosen for each stream such that the resulting streams have coding bit rates that are uniformly spaced in the log domain between lower and upper bounds.

[0091] During streaming, when the server reads a data unit from the media file, it includes the data unit in the virtual stream currently being transmitted if its Lagrange multiplier λ is above the threshold for the stream.

B. Leaky Bucket Computations at the Sender

[0092] For each virtual stream, leaky bucket parameters $(R, B_{\min}(R), F_{\min}^{d}(R))$ are pre-computed offline for $R = R_{avg}$ and $R = R_{\max}$, where $R_{avg} = r_c$ is the average coding bit rate of the stream, and $R_{max} = 2r_c$. These leaky bucket parameters are sent to the client in a preamble.

[0093] In addition, during streaming the server performs on-line leaky bucket simulations for each stream. Specifically, whenever the server reads a data unit from the media file, it determines the virtual streams to which the data unit belongs, using the Lagrange multiplier of the data unit and the list of thresholds for each stream. The sender then updates, for the determined streams, the states of those leaky buckets having leak rates equal to an average coding bit rate R_{avg}, using Eqs. (2) and (3). Once all the data units in a frame are read from the media file, the sender computes $g(n) = B_{\min}(R_{avg}) - B^e(n)$ for each of the virtual streams. On a stream switch (i.e., $\hat{r}_c(n) \neq \hat{r}_c(n-1)$), the gap $g^{new}(n)$ for the new stream is transmitted to the client along with $\Delta g(n\text{-}1)=g^{new}(n\text{-}1)\text{-}g^{old}(n\text{-}1)$ as described below. It is easy to see that the cost of updating the leaky bucket states is quite low. However, it is also possible to pre-compute these values and store them with each data unit in the media file.

C. Initial Coding bit rate Selection

[0094] At the beginning of a streaming session, the sender needs to have some knowledge of the available network bandwidth so that it can choose an initial coding bit rate (usually half of the bandwidth). The bandwidth estimate can be drawn from proactive measurements, using approaches such as packet pair [12], path chirp [3], etc., or reactive approximations based on history values. The exact form of the initial bandwidth estimation is beyond the scope of this work.

D. Coding bit rate Switching

[0095] The rate control feedback from the client contains the frame number at which feedback is generated (s.g., n -

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2 in the previous section) and the maximum allowable shift of the upper bound in bits (e.g., $\Delta^{max}g(n\text{-}1)$ in the previous section). If the sender finds a suitable coding bit rate and makes a switch at frame n, it will transmit three values to the client along with the frame: the new coding bit rate $\hat{r}_c^{new}(n)$, the current gap to the upper bound $g^{new}(n)$, and the shift $\Delta g(n\text{-}1) = g^{new}(n\text{-}1)\text{-}g^{old}(n\text{-}1)$. With this information, the client can properly adjust its control target schedule as well as its upper bound. Note that coding bit rate switching always happens at the beginning of a new frame, never inside a frame.

E. Optimal Rate Control at the Client

[0096] Whenever a new coding bit rate starts, the client receives the value $g(n)$ along with the new frame. The values of $g(n)$ for successive frames can be then inferred by the client itself based on the coding bit rate $\hat{r}_c(n)$ and the frame size $b(n)$. The client records the arrival frame time $t_a(n)$, calculates the buffer tube upper bound $t_b(n)$ and then computes the deviation $e(n)$. If there is a coding bit rate switch, it will also compute the buffer tube shift and adjust the control target schedule accordingly. Then, $e(n)$ is fed to the optimal rate controller, which outputs a desired new coding bit rate. The latest new coding bit rate is fed back to the sender whenever there is a feedback opportunity, which could be generated at regular intervals or on-demand.

F. Exemplary Process

[0097] An exemplary process for the implementation of the foregoing system will now be provided as applicable to one embodiment of the present invention.

[0098] Referring to Figs. 11A-C, the server first computes a set of parameters defining an initial state of the encoder buffer as it would exist if a data stream corresponding to a supported coding bit rate were streamed therefrom, for each of the supported coding bit rates (process action 1100). These parameters, which include the coding bit rate associated with the data stream, the size of the encoder buffer employed with the coding bit rate of the data stream, and a value indicative of the initial encoder buffer fullness exhibited at the coding bit rate of the data stream, are provided to the client in a preamble to the streaming media data (process action 1102). The server then streams the media data to the client at a prescribed initial coding bit rate, during a startup period (process action 1104). As the data is streamed, the server computes the upper bound gap for each frame generated for each coding bit rate supported by the server (process action 1106). Initially, the client employs the encoder buffer parameters to determine on a frame-by-frame basis a new, optimal coding bit rate for a future frame (process action 1108). In addition, the client computes the aforementioned maximum allowable difference value for the frame generated by the server just prior to the future frame, i.e., the maximum shift value (process action 1110). The client also begins playback of the frames it has received as soon as the client's decoder buffer has the minimum amount of data therein that is needed to ensure an underflow condition does not occur at the initial coding bit rate and continues to playback each frame received thereafter (process action 1112). In addition, once the aforementioned startup period is over, the client requests that the streaming media data be supplied at a new coding bit rate corresponding to the determined optimal coding rate, starting at the future frame, and provides the maximum shift value along with the request (process action 1114).

[0099] The server finds a supported coding bit rate that is equal to, or if none are equal, the closest smaller rate to, the optimum coding bit rate requested by the client (process action 1116). It is next determined by the server if the supported coding bit rate found is lower or higher than the coding bit rate associated with the frame generated immediately prior to the frame specified in the client request (process action 1118). If it is lower, then server computes the aforementioned shift value for the frame generated immediately prior to the frame specified in the client request (process action 1120), and generates all future frames beginning with the frame specified by the client at the supported rate found and streams them to the client, along with the computed upper bound gap and shift value, and an indication of the new coding bit rate (process action 1122). However, if the supported coding bit rate found is higher, then server computes the shift value for the frame generated immediately prior to the frame specified in the client request (process action 1124) and then determines if the shift value is less than or equal to the maximum shift value provided in the client request (process action 1126). If the shift value is less than or equal to the maximum shift value, then the server generates all future frames beginning with the frame specified by the client at the supported coding bit rate found and streams them to the client, along with the computed upper bound gap and shift value, and an indication of the new coding bit rate (process action 1122). But, if the shift value is greater than the maximum shift value, then the next lower supported coding bit rate is found (process action 1128) and the process actions 1118 through 1128 are repeated.

[0100] The client shifts the currently scheduled target arrival time associated with a just received first frame at the new coding bit rate by the shift value provided, and shifts the currently scheduled target arrival times for future frames such that they collectively approach, over a period of time, and eventually coincide with, the previous target arrival times for those frames (process action 1130). The client then employs the encoder buffer parameters and the upper bound gap value provided by the server to determine a new, optimal coding bit rate for a future frame and to compute the

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maximum shift value for the frame generated by the server just prior to the future frame (process action 1132). The client requests that the streaming media data be supplied at a new coding bit rate corresponding to the determined optimal coding rate starting at the future frame specified by the client, and includes the computed maximum shift value (process action 1134). Process actions 1116 through 1134 are then repeated for the duration of the streaming media data transmission.

VI. Multiple Bit Rate Streaming

[0101] Multiple bit rate (MBR) streaming is a network adaptive technique that is widely used in commercial streaming media systems. In MBR streaming, in contrast to scalable streaming, the content is encoded into several (typically 5-7) independent streams at different coding bit rates. Often, each stream is optimized for a common type of network connection (e.g., dial-up, DSL, cable). During an MBR streaming session, the proper coding bit rate is dynamically selected based on the available network bandwidth, with the goal of achieving the maximum possible quality under the condition of uninterrupted playback. It is easy to see that MBR streaming is analogous to scalable streaming. Indeed MBR streaming can be viewed as a special case of scalable streaming with a limited number of coding bit rates available. Hence, the foregoing optimal control approach should be applicable to this case.

[0102] There are, however, several differences that complicate MBR streaming, which need to be carefully addressed. First, as just mentioned, in MBR streaming there are only a limited number of coding bit rates available. This coarse quantization of the desired coding bit rate introduces a significant nonlinearity into the closed loop system. In fact, the large gaps between the available coding bit rates introduce oscillations. For example, if two neighboring coding bit rates straddle a constant arrival rate, the controller will oscillate between the two coding bit rates in an attempt to keep the client buffer at a target level.

[0103] Second, in MBR streaming the coding bit rate cannot be switched at an arbitrary time. In fact, before the server can switch to a new stream, it may have to wait for the next clean point (e.g., I frame) in the new stream, which could be five or ten seconds away. Thus, the old coding bit rate may continue for quite a while before it changes to the new coding bit rate. From the controller's perspective, this long random extra delay tends to destabilize the closed-loop system.

[0104] Third and finally, in MBR streaming, server performance issues are critical. The commercial-grade streaming media systems that use MBR streaming do so because of the minimal computational load that it imposes on the server compared to scalable streaming. Thus, for MBR streaming it is important to keep almost all computation and state maintenance on the client side. In particular, the server will not be able to update the leaky bucket information for each stream. Instead, the client must use some mechanism for estimating and maintaining this information.

A. Conservative Up-Switching

[0105] In this subsection, a technique to help stabilize the control system and reduce steady state oscillations to a period of at least a minute is described. With this technique, rapid down-switching is permitted. In fact, the value of σ is reduced from 2000 to 500, changing the balance between responsiveness and smoothness of the coding bit rate in favor of rapid switching response. However, only conservative up-switching is permitted. Conservative up-switching ensures that spurious changes in coding bit rate do not occur, and that oscillations in the coding bit rate have a low frequency. In particular, conservative up-switching reduces the oscillations between two adjacent but widely spaced MBR coding bit rates, one above the arrival rate and one below the arrival rate.

[0106] In one embodiment, conservative up-switching establishes a conservative limit that limits the coding bit rate to no more than the arrival rate. However, in another embodiment, the method behind conservative up-switching is to establish a conservative limit on how high the coding bit rate can be raised above the arrival rate. If the current coding bit rate is below the arrival rate, and the client buffer duration begins to increase above its target level, then the coding bit rate can be switched up to a new coding bit rate above the arrival rate only if the new coding bit rate is below the conservative limit. When the client buffer duration begins at the target level, the conservative limit is equal to the arrival rate. However, as the client buffer duration increases, the conservative limit increases as well. Thus, if the current coding bit rate is below the arrival rate, and the next higher coding bit rate is above the arrival rate, then it will be possible to switch up to the next higher coding bit rate only after the client buffer duration has increased sufficiently so that the conservative limit rises above the higher coding bit rate. Once the coding bit rate is switched up to the higher coding bit rate, the client buffer begins to drain since the coding bit rate is then above the arrival rate. Eventually, when the buffer drains back below its target level, the controller will rapidly switch the coding bit rate back down to the coding bit rate below the arrival rate.

[0107] Given the current client buffer duration, the conservative limit is set to a value such that if the coding bit rate is switched up to a new coding bit rate at this value, the client buffer would take at least Δt seconds of client time to drain back to the target level. Thus, the mechanism ensures that the period of oscillation will be at least Δt seconds. In tested embodiments of the present system and process, Δt is set to 60 seconds.

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[0108] Fig. 12 shows how the conservative limit is computed. Let $\Delta\tau_1$ be the client buffer duration (in media time) at the moment that the coding bit rate is switched up from r_c^{old} to r_c^{new}. Thus $\Delta\tau_1$ is the number of seconds of content that will be consumed at the old coding bit rate r_c^{old} before content at the new coding bit rate begins to be consumed. (For simplicity it is assumed that all of the content in the client buffer at the time of the switch is coded at rate r_c^{old}.) Let $\Delta\tau_2$ be the number of seconds of content that is consumed at the new coding bit rate r_c^{new} before the client buffer duration drops to some level $\Delta\tau_3$ seconds (in media time), greater than the target level $\Delta\tau_T$. The duration of this phase is determined such that the total time since the switch is exactly $\Delta t = (\Delta\tau_1 + \Delta\tau_2)/v$ seconds (in client time). Now, the number of bits that arrive in this time is $r_a \Delta t = r_c^{new}(\Delta\tau_2 + \Delta\tau_3) \geq r_c^{new}(\Delta\tau_2 + \Delta\tau_T) = r_c^{new}(v\Delta t - \Delta\tau_1 + \Delta\tau_T)$, or

$$r_c^{new} \leq \frac{r_a \Delta t}{v\Delta t - \Delta\tau_1 + v\Delta t_T}, \tag{60}$$

where Δt_T is the target buffer duration in client time. The parameter Δt can be tuned to yield the desired behavior. A large Δt means that up-switching will be more conservative, while a smaller Δt means that up-switching will be more prompt. In tested embodiments, Δt is set to 60 seconds while the target Δt_T is typically about 10 seconds.

B. Buffer Tube Upper Bound Estimation

[0109] In Section V-D it was specified that the server sends three values to the client at the beginning of each change in coding bit rate: the new coding bit rate $\hat{r}_c^{new}$, the current gap to the upper bound $g^{new}(n)$, and the control target shift $\Delta g(n-1) = g^{new}(n-1) - g^{old}(n-1)$. The server computes the latter two values by running a leaky bucket simulator for each coding bit rate. The client continues to update $g(n)$ for the new coding bit rate by running its own leaky bucket simulator for the new coding bit rate. That is, beginning with the initial condition $F^e(n) = B - b(n) - g^{new}(n)$, for each successive frame the client computes

$$B^e(n) = F^e(n) + b(n) \tag{61}$$

$$F^e(n+1) = \max\{0, B^e(n) - \hat{r}_c f(n)\}, \tag{62}$$

where

$$f(n) = \frac{1}{\tau(n+1) - \tau(n)} \tag{63}$$

is the instantaneous frame rate, as in Eqs. (2), (3) and (4). From this, the client can compute

$$g(n) = B - B^e(n) \tag{64}$$

for each frame.

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[0110] However, if the server is unable to simulate the leaky buckets and cannot send $g^{new}(n)$ to the client, then the client must estimate this information for itself. In this case it is recommended that the client estimates $g^{new}(n)$ as an upper bound such as $\hat{g}^{new}(n)=B-b(n)\geq g^{new}(n)$. Then, beginning with initial condition $\hat{F}^{e}(n)=B-b(n)-g^{new}(n)$ (which equals 0 in this case), for each successive frame the client computes

$$\hat{B}^{e}(n) = \hat{F}^{e}(n) + b(n) \tag{65}$$

$$\hat{F}^{e}(n+1) = \max\{0, \hat{B}^{e}(n) - \hat{r}_c/f(n)\}, \tag{66}$$

as well as

$$\hat{g}(n) = B - \hat{B}^{e}(n). \tag{67}$$

It is easy to see by induction that $\hat{F}^{e}(n) \leq F^{e}(n)$, $\hat{B}^{e}(n) \leq B^{e}(n)$, and $\hat{g}(n) \geq g(n)$. Moreover, these bounds each become tighter by $\delta(n) = \hat{r}_c/f(n) - B^{e}(n)$ whenever $\delta(n) > 0$, i.e., whenever $F^{e}(n+1)$ is clipped to 0 in Eq. (66). In fact, given enough time they may eventually become tight.

[0111] Note that whenever the bounds tighten by $\delta(n) > 0$, the control target must be shifted by $\Delta g(n)/\tilde{r}_a$, where $\Delta g(n) = -\delta(n)$. Furthermore, whenever n is the first frame of a new coding bit rate, the control target should be shifted by $\Delta g(n)/\tilde{r}_a$, where $\Delta g(n) = \hat{g}^{new}(n)-\hat{g}^{old}(n)$. Here, $\hat{g}^{old}(n)$ can be determined by running Eqs. (65), (66) and (67) for one extra step, namely if n is the first frame of the new coding bit rate,

$$\hat{F}^{e}(n) = \max\{0, \hat{B}^{e}(n-1) - \hat{r}_c^{old}/f(n-1)\} \tag{68}$$

$$\hat{B}^{e}(n) = \hat{F}^{e}(n) + b(n) \tag{69}$$

$$\hat{g}^{old}(n) = B - \hat{B}^{e}(n). \tag{70}$$

It is easy to see that if $\hat{g}^{new}(n) = B - b(n)$, then $\Delta g(n)=\hat{F}^{e}(n)$ as computed in Eq. (68).

VII. Sender-Driven Streaming

[0112] The preceding discussions have assumed that the control process for adapting the stream or its bit rate to the prevailing conditions is located within the client. This is called *receiver-driven* streaming because the client (i.e., the receiver) makes the decisions and informs the server (i.e., the sender). However, it should be clear that sender-driven streaming is also possible, in which the control process operates at the sending side. For example, using TCP for transmission of the streaming media data, the control process can operate at the server, measuring the transmission times of each frame and estimating the transmission rate, instead of the control process operating at the client, measuring the arrival times of each frame and estimating the arrival rate. Using TCP, the transmission time of a frame is substantially the same as its arrival time, and likewise the transmission rate is substantially the same as its arrival rate; hence these can be used interchangeably. Generally, the transmission time or the arrival time of a packet may be called a time stamp. In sender-driven streaming, the server can infer the state of the client buffer by knowing what it has already transmitted and by knowing the playout times for the transmitted frames. Sender-driven streaming reduces the overhead of communicating control information between the client and the server, but it also increases the computational burden on the server. In some situations, this may be a desirable trade-off. Those skilled in the art will appreciate that it is possible to appropriately modify the protocols described herein to cases where the control algorithm resides in the server or in

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another location, rather than in the client.

VIII. References

[0113]

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Claims

1. A computer-implemented process for controlling a coding bit rate of streaming media data being transmitted to a client from a server over a computer network, comprising performing the following process actions:

   employing a linear quadratic control technique to establish, on an ongoing basis, a current coding bit rate for the streaming media data, which is estimated to provide a high quality playback of the streaming media data while still keeping a decoder buffer of the client used to receive streaming media data from the server filled to a desired duration level so as to reduce the chance of an underflow condition which would result in an interruption of the playback of the streaming media data by the client;
   using each coding bit rate established to control said rate for the streaming media data.

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2. The process of Claim 1, wherein the process action of establishing the current coding bit rate comprises the actions of:

determining on a frame-by-frame basis the coding bit rate which is estimated to keep the client buffer level approximately at the desired target level; and
establishing a new coding bit rate only when it is determined the coding bit rate estimate will not change in relation to the last established rate by more than a desired degree.

3. The process of Claim 2, wherein the client buffer level is determined by a leaky bucket model of the streaming media data at the estimated coding bit rate.

4. The process of Claim 3, wherein the process action of determining on a frame-by-frame basis the coding bit rate which is estimated will keep the client buffer approximately at the desired level, comprises an action of identifying a coding bit rate that reduces a difference between an estimated latest anticipated arrival time of the frame under consideration and a prescribed target arrival time.

5. The process of Claim 4, wherein the process action of determining on a frame-by-frame basis the coding bit rate which is estimated will keep the client buffer approximately at the desired level, comprises an action of reducing the change in the coding bit rate to a prescribed degree, using a quadratic cost function.

6. The process of Claim 5, wherein the process action of estimating the latest anticipated arrival time of the frame under consideration, comprises the actions of:

re-estimating the latest anticipated arrival time associated with the frame immediately preceding the frame under consideration if it were to exhibit the current coding bit rate; and
adding said re-estimated time to the current coding bit rate divided by the product of a current instantaneous frame rate and an estimated arrival rate of the frames.

7. The process of Claim 6, wherein the process action of re-estimating the latest anticipated arrival time associated with the frame immediately preceding the frame under consideration comprises adding the actual arrival time of said immediately preceding frame as measured by the client, to an upper bound gap of an encoder buffer of the server for the immediately preceding frame divided by the estimated arrival rate associated with said immediately preceding frame, wherein the upper bound gap of a frame is defined as the number of data bits that the server's encoder buffer can contain over the bits currently contained therein after the frame is fully input into the encoder buffer.

8. The process of Claim 7, wherein the process action of establishing the current coding bit rate is accomplished by the client, and wherein the client estimates the latest anticipated arrival time of the frame under consideration based on information received from the server concerning the state of the encoder buffer.

9. The process of Claim 8, wherein the information received from the server comprises the current coding bit rate of the streaming media data being received by the client which is received as part of the first frame of the sequence of frames exhibiting that coding bit rate.

10. The process of Claim 9, further comprising, an action of estimating the upper bound gap for each frame received by the client, said estimating comprising:

computing what the encoder buffer fullness value would have been after the last received frame was placed therein as the sum of the last computed value of the encoder buffer fullness prior to insertion of the last received frame and the size of that last received frame,

wherein the encoder buffer fullness value prior to insertion of the last received frame associated with the first frame received by the client at the current coding bit rate of the streaming media is assumed to be zero regardless of its actual value,
and wherein the encoder buffer fullness value prior to insertion of the last received frame associated with each subsequent frame received by the client at the current coding bit rate is deemed to be either zero, or the difference between the last computed value for the encoder buffer fullness after the insertion of the last received frame and the coding bit rate divided by the instantaneous frame rate, whichever is larger, wherein the instantaneous frame rate is equal to the reciprocal of a scheduled playback time of the next frame to be received less a scheduled playback time of the last received frame; and

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computing the upper bound gap associated with the last received frame as the encoder buffer size less the last computed value for the encoder buffer fullness after insertion of the last received frame.

11. The process of Claim 10, wherein the encoder buffer size varies depending on the coding bit rate and is received by the client from the server as a preamble to the streaming media data for all coding bit rates available from the server.

12. The process of Claim 10, further comprising, whenever a frame is received by the client which has a different coding bit rate than the immediately preceding frame, the actions of:

shifting the currently scheduled target arrival time associated with the just received frame by a shift value, wherein said shift value represents a difference between the upper bound gap of the frame and the upper bound gap that would be associated with the frame had it been coded at the immediately preceding coding bit rate;
shifting the currently scheduled target arrival times for future frames such that they, collectively approach over a period of time, and eventually coincide with, the previous target arrival times for those frames; and
shifting each shifted frame by the difference between the encoder buffer fullness value after insertion of the last received frame and the current coding bit rate, divided by the frame rate, and then divided by the estimated arrival rate associated with the last received frame.

13. The process of Claim 12, wherein the upper bound gap that would be associated with the frame had it been coded at the immediately preceding coding bit rate is computed as the encoder buffer size less the last computed value for the encoder buffer fullness value after insertion of the last received frame, wherein the encoder buffer fullness value after insertion of the last received frame is computed as the sum of the last computed value of the encoder buffer fullness value prior to insertion of the last received frame and the size of that last received frame, and wherein the encoder buffer fullness value prior to insertion of the last received frame is computed as either zero, or the difference between the value computed for the encoder buffer fullness after the insertion of the frame received prior to the last received frame and the immediately preceding coding bit rate divided by the instantaneous frame rate associated with the frame received prior to the last received frame, whichever is larger.

14. The process of Claim 8, wherein the information received from the server comprises:

the current coding bit rate of the streaming media data being received by the client which is received as part of the first frame of the sequence of frames exhibiting that coding bit rate; and
the current upper bound gap which is received as part of every frame.

15. The process of Claim 8, wherein the information received from the server comprises:

the current coding bit rate of the streaming media data being received by the client which is received as part of the first frame of the sequence of frames exhibiting that coding bit rate; and
the current upper bound gap associated with the first frame of the sequence of frames exhibiting the current coding bit rate, said current upper bound gap also being received as part of the first frame of said sequence.

16. The process of Claim 15, wherein the information received from the server further comprises a shift value which is received as part of the first frame of the sequence of frames exhibiting a coding bit rate that is different from the immediately preceding frame, said shift value representing a difference between the upper bound gap that would be associated with the immediately preceding frame received by the client had it been coded at the current coding bit rate and the upper bound gap actually associated with the immediately preceding frame coded at the previous coding bit rate.

17. The process of Claim 16, further comprising an action of whenever a frame is received by the client which has a different coding bit rate than the immediately preceding frame, shifting the currently scheduled target arrival time associated with the just received frame by the shift value and shifting the currently scheduled target arrival times for future frames such that they collectively approach over a period of time and eventually coincide with the previous target arrival times for those frames, said shifting of the target values being accomplished so as to prevent the client from attempting to establish new coding bit rates based on the shift in the upper bound gap between the old and new coding bit rates rather than a change in the arrival rate of the frames.

18. The process of Claim 15, further comprising, for each frame received by the client that is not the first frame of the sequence of frames exhibiting the current coding bit rate, an action of estimating the upper bound gap.

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19. The process of Claim 6, wherein computing the estimated arrival rate of the frames of the streaming media data comprises:

computing, on a packet-by-packet basis, the product of the estimated arrival rate computed for the immediately preceding packet to the currently received packet and a first fractional weighting factor, added to the product of the instantaneous arrival rate of the currently received packet and a second fractional weighting factor, wherein at least one of the fractional weighting factors is not a constant but instead based on the time between the packets.

20. The process of Claim 5, wherein the process action of identifying the coding bit rate that reduces the difference between the estimated latest anticipated arrival time of the frame under consideration and the prescribed target arrival time, while at the same time reducing the change in the coding bit rate to a prescribed degree, comprises an action of choosing the prescribed target arrival time for the frame under consideration so as to be a prescribed amount of time earlier than a scheduled playback time for that frame.

21. The process of Claim 20, wherein the process action of choosing the prescribed target arrival time for the frame under consideration comprises an action of making said prescribed amount of time large enough after a startup period that network jitter, delays and throughput changes which may cause the actual arrival time of the frame to be after its target arrival time do not result in the frame arriving after its scheduled playback time.

22. The process of Claim 21, wherein the process action of choosing the prescribed target arrival time for the frame under consideration further comprises making the target arrival time closer to the playback time during the startup period than afterwards for those frames arriving during that period to assist in reducing a startup delay between when the streaming media data begins to be received by the client and when the first frame is played back.

23. The process of Claim 22, wherein the process action of choosing the prescribed target arrival time for the frame under consideration further comprises setting the target arrival time for each frame of the streaming media using a logarithmic target schedule.

24. The process of Claim 22, wherein the process action of choosing the prescribed target arrival time for the frame under consideration further comprises setting the target arrival time for each frame of the streaming media using a two-piece linear target schedule wherein the difference between the target arrival time and the playback time for a frame arriving during the startup period increases linearly to a prescribed amount of time that is large enough to account for said network jitter, delays and throughput changes after which the difference remains substantially constant.

25. The process of Claim 22, further comprising a process action of reducing the startup delay, said reducing action comprising beginning playback of the first frame of the streaming media data as early as when a decoder buffer of the client has a minimum amount of data therein that is needed to ensure an underflow condition does not occur at an initial coding bit rate.

26. The process of Claim 25, wherein the process action of beginning playback of the first frame of the streaming media data as early as when the decoder buffer of the client has a minimum amount of data therein, comprises the actions of:

obtaining an initial encoder buffer fullness value associated with said first frame, wherein the initial encoding buffer fullness value is defined as the size of the encoder buffer less the size of the first frame and less the upper bound gap associated with the first frame;
establishing said minimum amount of data as the encoder buffer size associated with the initial coding bit rate less an initial encoder buffer fullness.

27. The process of Claim 26, wherein the initial coding bit rate, initial encoder buffer fullness, and encoder buffer size are received from the server as a preamble to the streaming media data.

28. The process of Claim 26, wherein the process action of reducing the startup delay further comprises setting the initial coding bit rate to a level that is less than the anticipated arrival rate of the streaming media data at the client since said minimum amount of data decreases as the arrival rate increases relative to the coding bit rate and the startup delay is substantially said minimum amount of data divided by the arrival rate so if the coding bit rate is less than the arrival rate, said minimum amount of data required may be smaller and the startup delay may be less.

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29. The process of Claim 5 wherein the process action of establishing the current coding bit rate comprises an action of initiating the establishment of coding bit rates only after a startup period, wherein said startup period is defined as the period of time prior to the first instance of an estimated latest arrival time of a frame under consideration computed for the initial coding bit rate being earlier than a target arrival time for that frame.

30. The process of Claim 5, wherein the prescribed degree to which the change in the coding bit rate is reduced varies depending on whether the coding bit rate increased, in which case the prescribed degree to which any future change in the coding bit rate is reduced is made greater in comparison to the prescribed degree in cases where the last change in the coding bit rate decreased the rate.

31. The process of Claim 3, wherein the process action of establishing a current coding bit rate for the streaming media data, comprises, in the case where the determined coding bit rate represents an increase from the immediately previous coding bit rate, establishing a new coding bit rate only if the new rate does not exceed the current estimated arrival rate of the frames.

32. The process of Claim 3, wherein the process action of establishing a current coding bit rate for the streaming media data, comprises, in the case where the determined coding bit rate represents an increase from the immediately previous coding bit rate which exceeds the current estimated arrival rate of the frames, establishing a new coding bit rate only if the current client buffer exceeds the desired level by an amount that it is estimated by the client will not be expended at the higher coding bit rate prior to the passing of a prescribed period of time.

33. The process of Claim 3, wherein the process action of establishing a current coding bit rate for the streaming media data, comprises, in the case where the determined coding bit rate represents a decrease from the immediately previous coding bit rate, establishing a new coding bit rate even if it represents a significant departure from the immediately previous coding bit rate.

34. A computer-implemented process for controlling a coding bit rate of streaming media data being transmitted to a client from a server over a computer network, comprising using the server to perform the following process actions:

generating a streaming media data stream which exhibits a coding bit rate supported by the server, and which after an initial startup period exhibits a coding bit rate related to a rate requested by the client;
computing parameters indicative of the state of an encoder buffer of the server, said encoder buffer being used to stage portions of the streaming media data prior to transmission to the client; and
providing the encoder buffer state parameters and the streaming media data stream to the client, whereby said parameters are usable by the client to establish, on an ongoing basis, a current coding bit rate for the streaming media data, which is estimated will provide a high quality playback of the streaming media data while still keeping a decoder buffer of the client used to receive streaming media data from the server filled to a desired duration level so as to reduce the chance of an underflow condition which would result in an interruption of the playback of the streaming media data by the client.

35. The process of Claim 34, wherein the process action of computing parameters indicative of the state of an encoder buffer, comprises an action of, for each coding bit rate supported by the server, computing a set of parameters defining an initial state of the encoder buffer as it would exist if a data stream corresponding to the coding bit rate where streamed therefrom, wherein said encoder buffer parameters comprise the coding bit rate associated with the data stream, the size of the encoder buffer employed with the coding bit rate of the data stream, and a value indicative of the initial encoder buffer fullness exhibited at the coding bit rate of the data stream.

36. The process of Claim 35, wherein the process action of providing the encoder buffer state parameters and the streaming media data stream to the client, comprises an action of providing the encoder buffer parameters computed for each data stream exhibiting one of the supported coding bit rates to the client as part of a preamble sent to the client prior to sending the streaming media data.

37. The process of Claim 35, wherein the size of the encoder buffer employed with the coding bit rate of the data stream is chosen so as to be the minimum size buffer that will still contain the data stream at any point in the streaming process given the coding bit rate and the initial encoder buffer fullness.

38. The process of Claim 35, further comprising a process action of the server computing an upper bound gap for each frame of the streaming media data generated for each coding bit rate supported by the server, wherein the upper

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bound gap is defined as the number of data bits that the server's encoder buffer can contain over the bits currently contained therein after the just-generated frame is fully input into the encoder buffer.

39. The process of Claim 38, further comprising a process action of providing the upper bound gap computed for the first frame of a sequence of frames exhibiting a coding bit rate that is different from that associated with the frame generated immediately before the first frame of said sequence of frames, to the client along with an indication of the coding bit rate associated with the sequence of frames, said gap value and coding bit rate being provided with said first frame of the sequence.

40. The process of Claim 39, wherein the client estimates the upper bound gap for frames provided by the server that do not include the associated gap value.

41. The process of Claim 40, wherein the client employs the encoder buffer parameters and the upper bound gap values to determine on a frame-by-frame basis the coding bit rate that will keep the client buffer approximately at the desired level, said determining comprising identifying a coding bit rate that reduces a difference between an estimated latest anticipated arrival time of the frame under consideration and a prescribed target arrival time.

42. The process of Claim 39, further comprising the process actions of:

the server computing a shift value for each frame representing the first frame of the sequence of frames exhibiting a coding bit rate that is different from the frame generated immediately before this first frame of the sequence, said shift value representing a difference between the upper bound gap that would be associated with the frame generated immediately before the first frame of the sequence had it been encoded at the current coding bit rate and the upper bound gap actually associated with the frame generated immediately before the first frame of the sequence encoded at the previous coding bit rate; and
providing the shift value computed for the first frame of each sequence of frames exhibiting a coding bit rate that is different from the frame generated immediately before the first frame of the sequence, to the client with the data comprising this first frame.

43. The process of Claim 42, wherein whenever a frame is provided to the client which has a different coding bit rate than the immediately preceding frame, the currently scheduled target arrival time associated with the just received frame is shifted by the shift value provided with the just-received frame and the currently scheduled target arrival times for future frames are shifted such that they collectively approach over a period of time and eventually coincide with the previous target arrival times for those frames.

44. The process of Claim 38, wherein a limited number of coding bit rates are supported by the server, and wherein the process action of generating a streaming media data stream which exhibits a coding bit rate supported by the server, and which after an initial startup period exhibits a coding bit rate related to a rate requested by the client, comprises the actions of:

(a) receiving a coding bit rate request from the client;
(b) finding a supported coding bit rate that is equal to, or if none are equal, the closest smaller rate to, the requested coding bit rate;
(c) whenever a supported coding bit rate is found that is a lower rate than the coding bit rate associated with the last generated frame of the streaming media data, generating all future frames at that supported rate; and
(d) whenever a supported coding bit rate is found that is a higher rate than the coding bit rate associated with the last generated frame of the streaming media data, determining if a difference, between the upper bound gap associated with the last generated frame had it been encoded at the supported coding bit rate found and the upper bound gap associated with that frame encoded at the current coding bit rate, is less than or equal to a maximum allowable difference value,

whenever the difference is less than the maximum allowable difference value, generating all future frames at the found supported rate, and
whenever the difference is not less than the maximum allowable difference value, finding the next lower supported coding bit rate and repeat actions (c)-(d).

45. The process of Claim 44, wherein the maximum allowable difference value is received from the client along with the coding bit rate request.

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46. The process of Claim 45, wherein the client chooses the maximum allowable difference value such that a latest anticipated arrival time associated with a frame provided by the server immediately prior to a frame under consideration by the client had it been coded at the requested coding bit rate is no more than a prescribed fraction of the way from that frame's target arrival time to its playback deadline.

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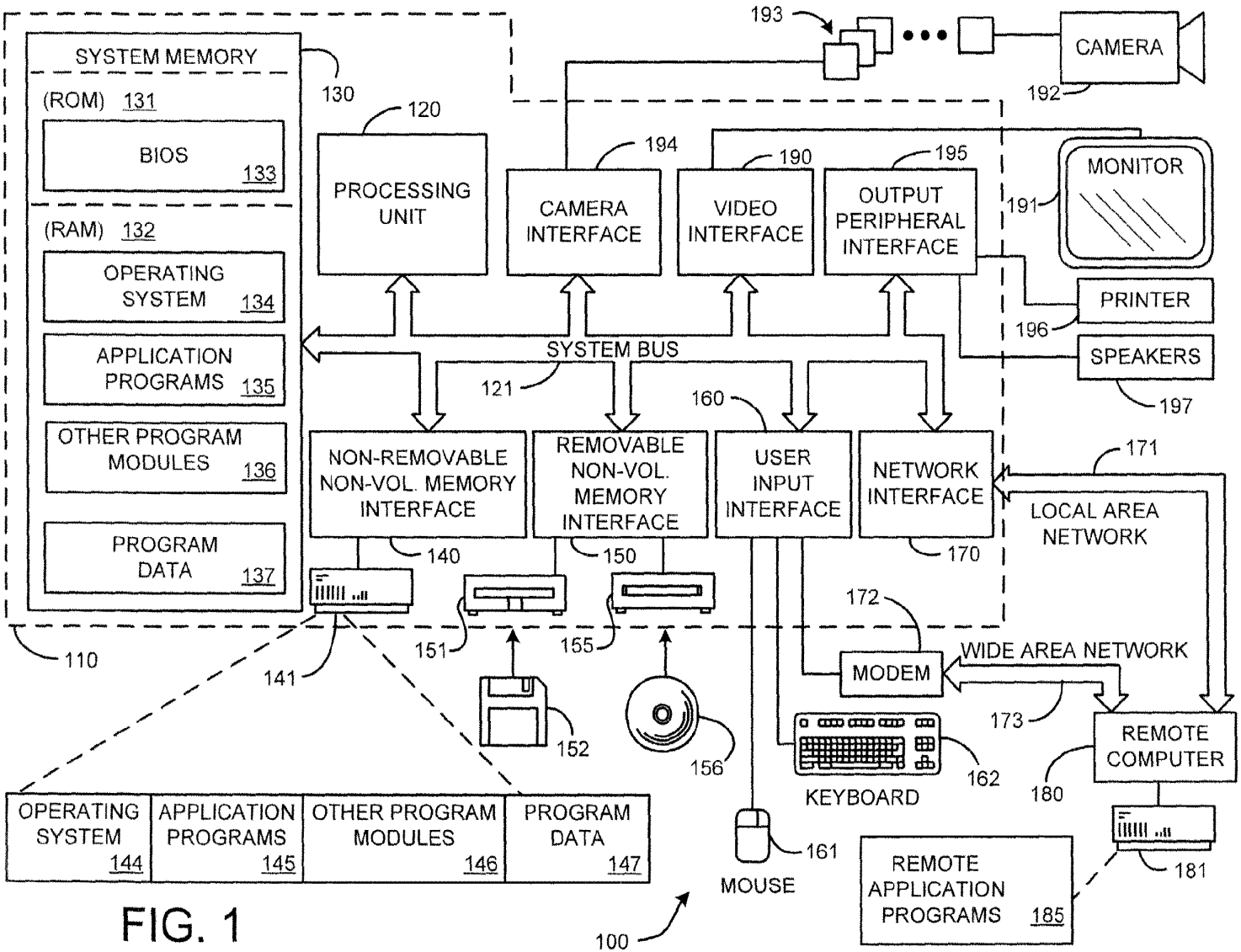


FIG. 1

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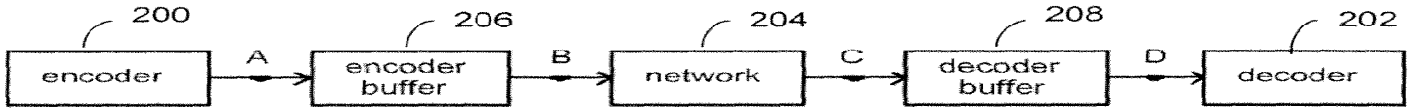


FIG. 2

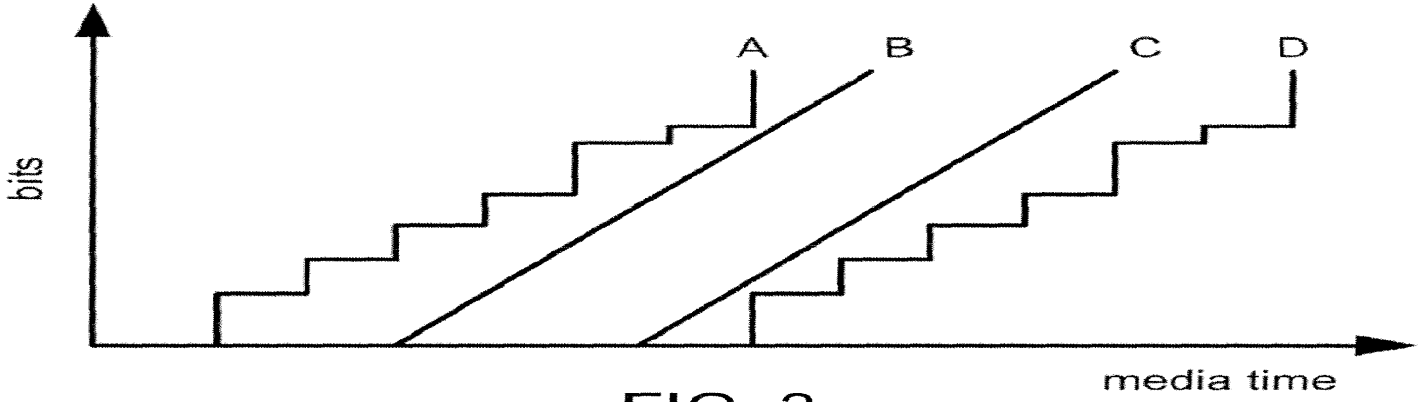


FIG. 3

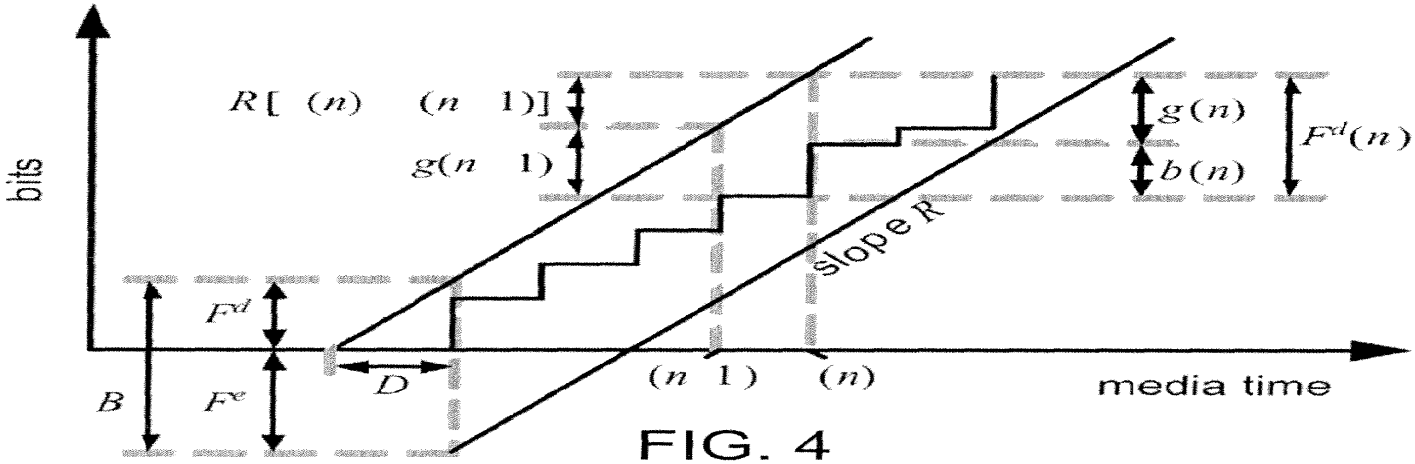


FIG. 4

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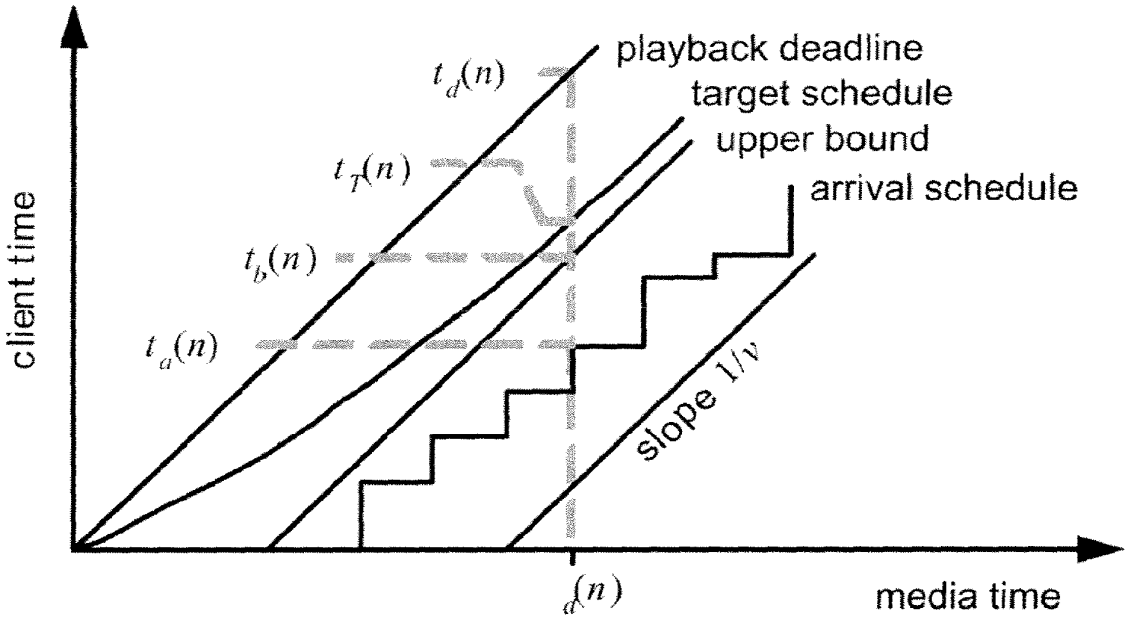


FIG. 5

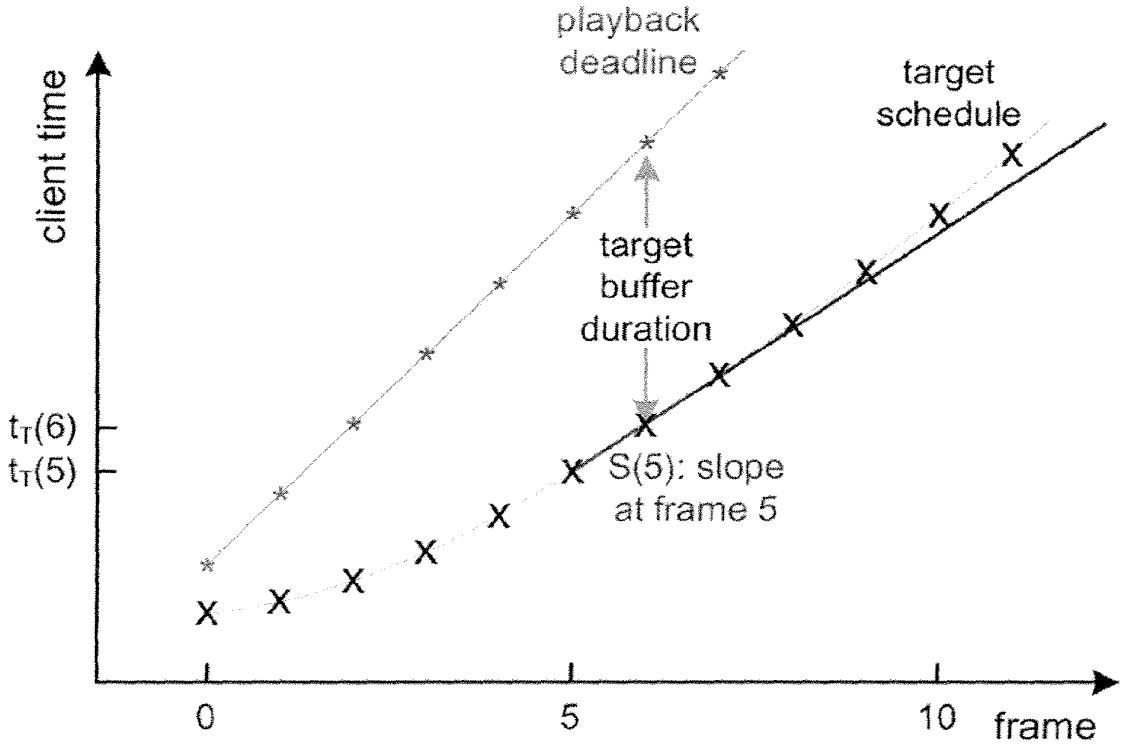


FIG. 6

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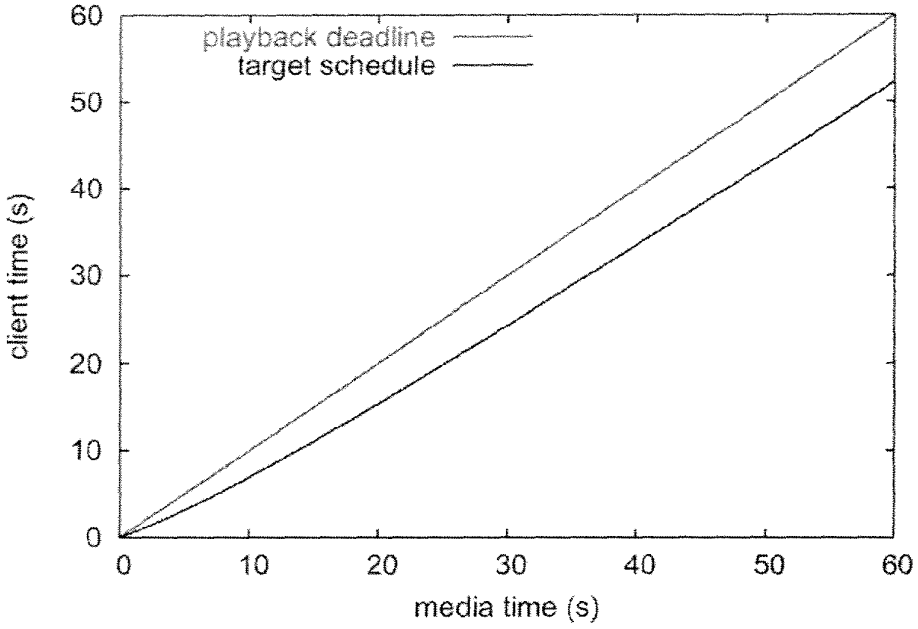


FIG. 7(a)

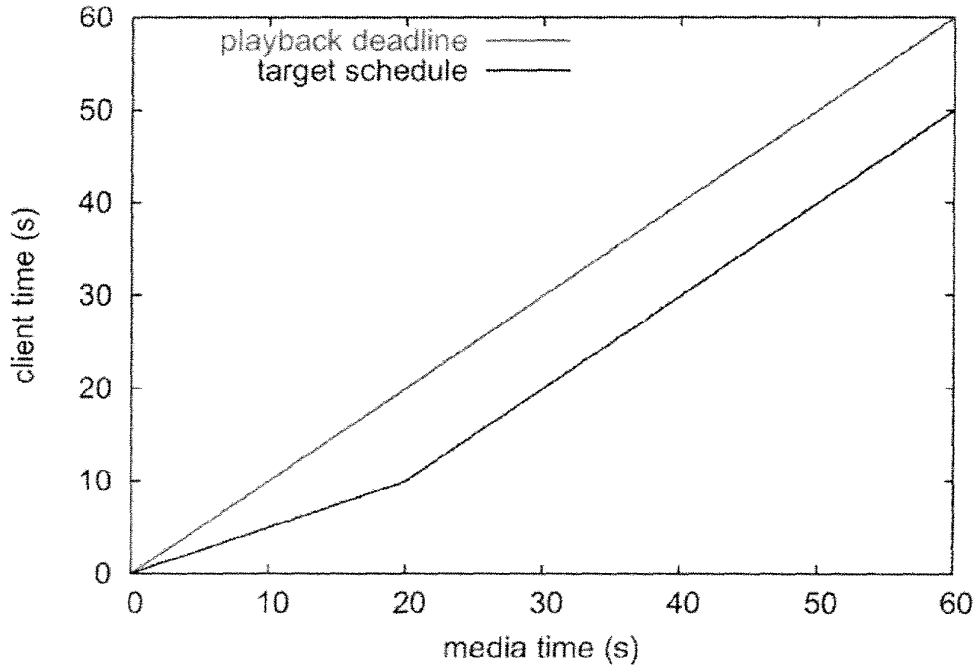


FIG. 7(b)

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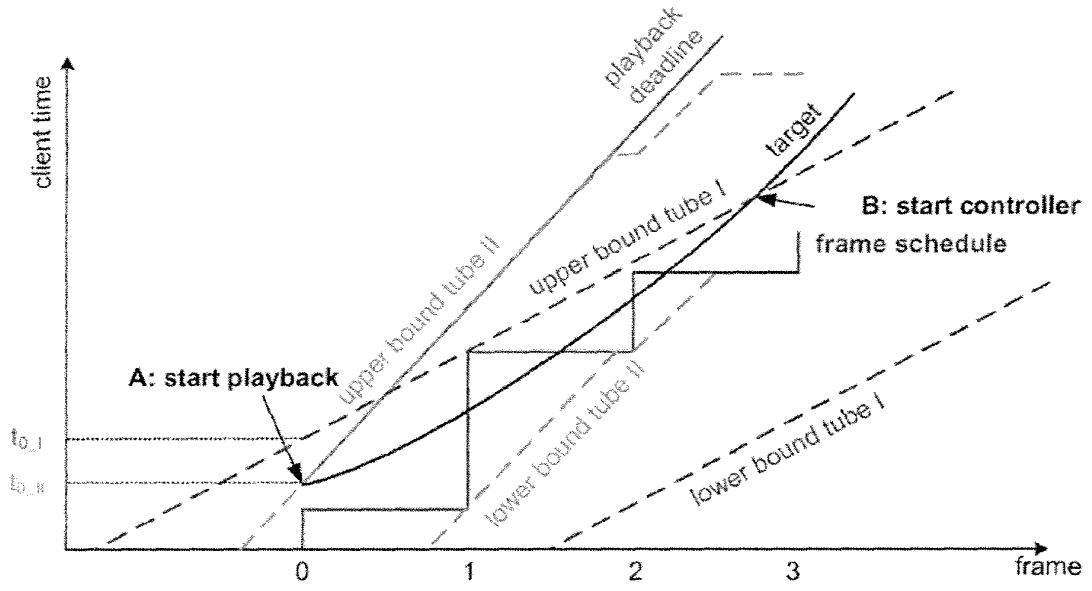


FIG. 8

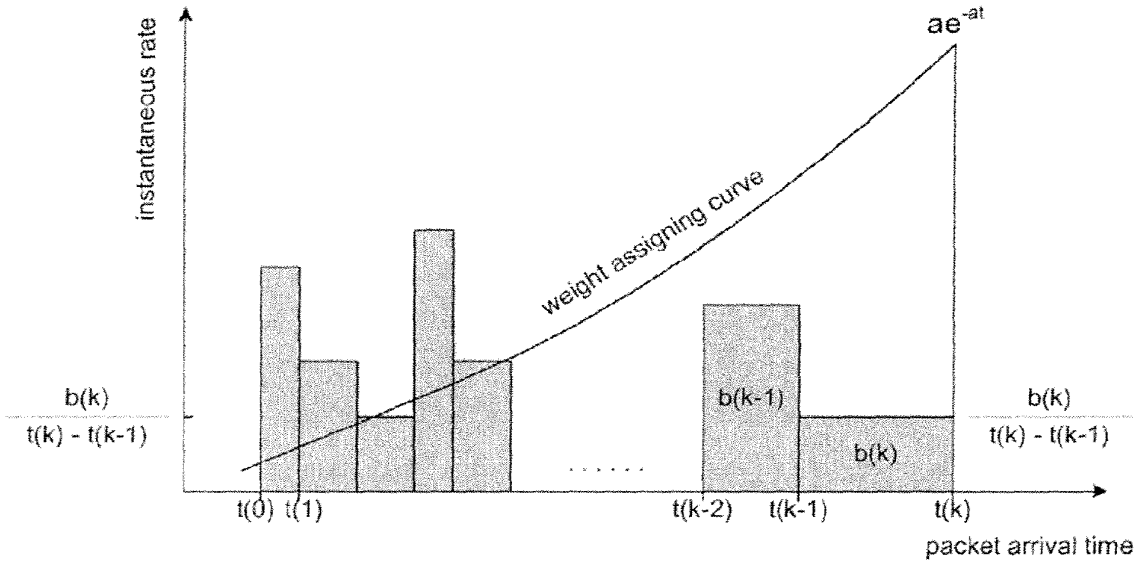


FIG. 9

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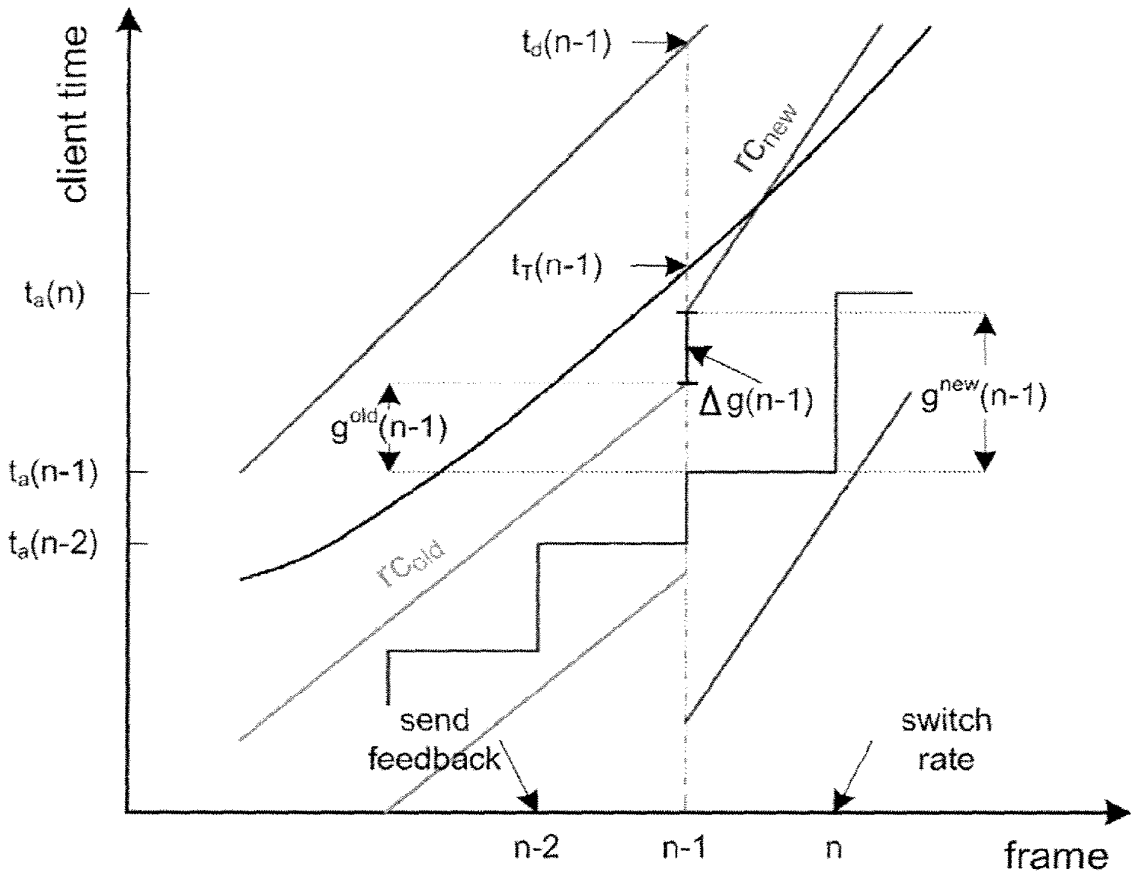


FIG. 10

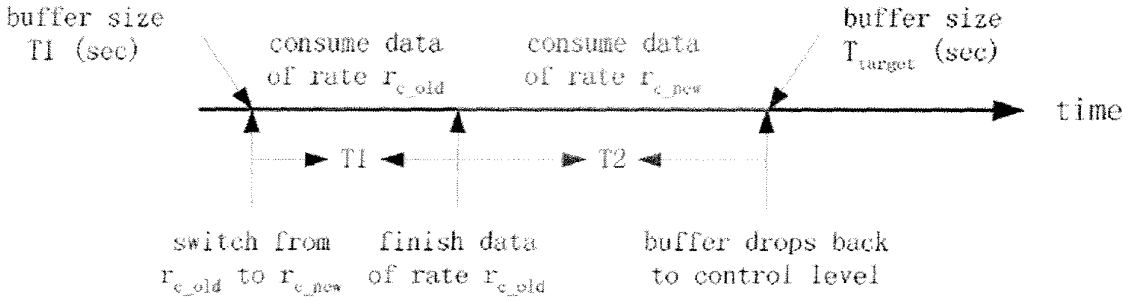


FIG. 12

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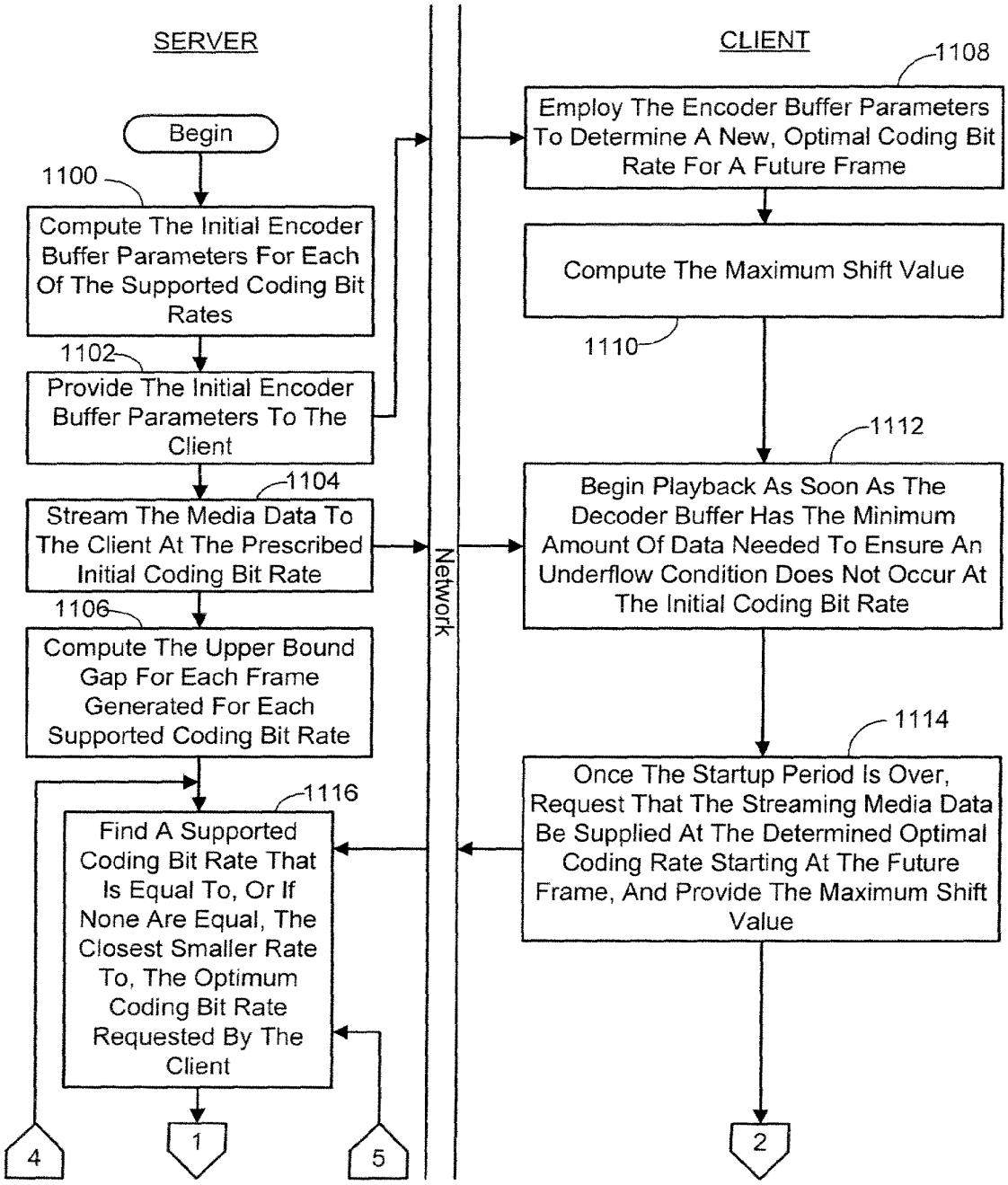


FIG. 11A

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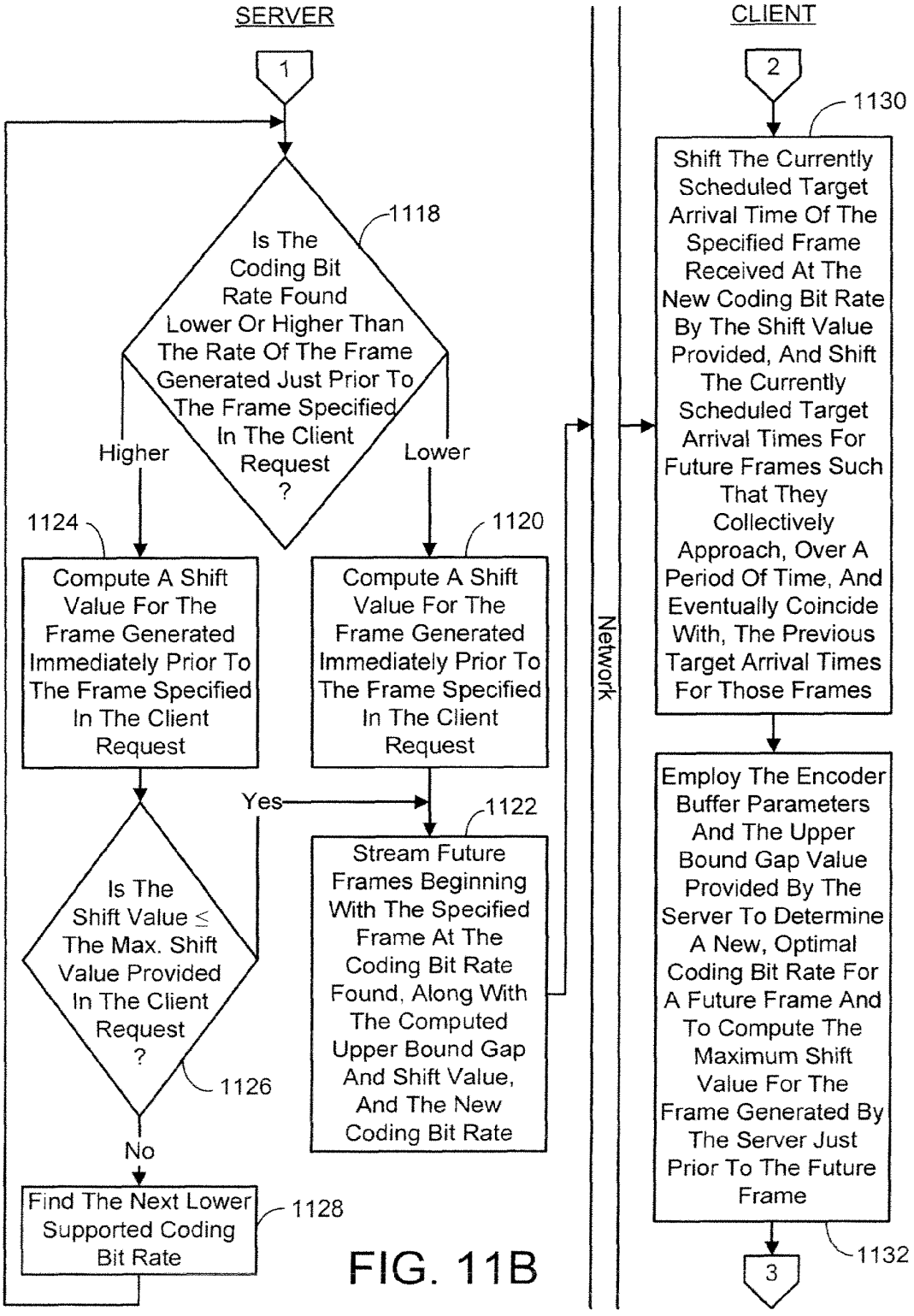


FIG. 11B

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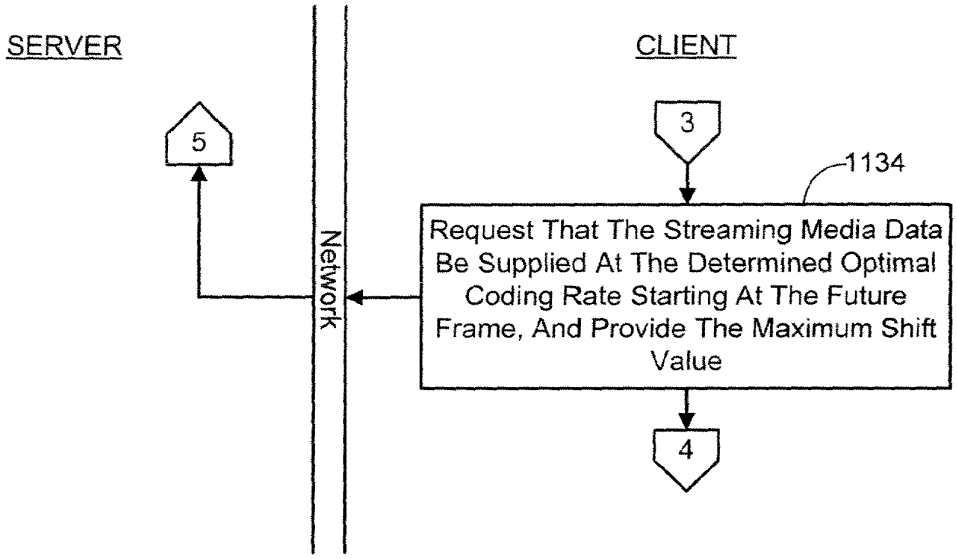


FIG. 11C

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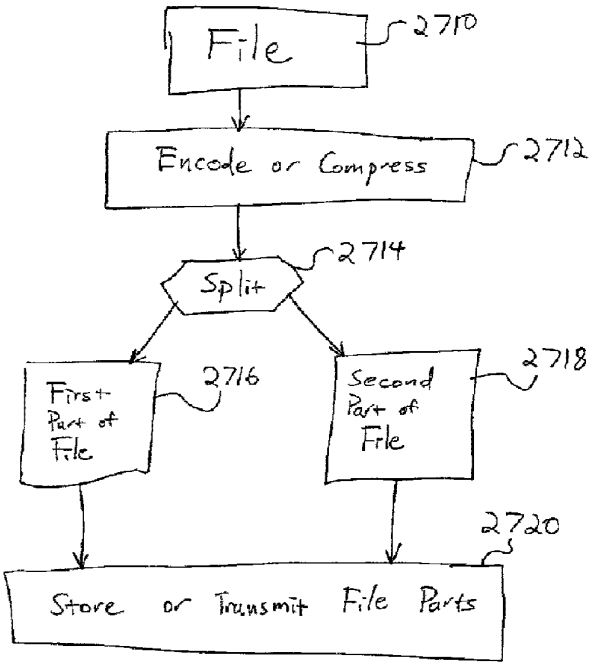
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(54) DECOUPAGE DE FICHIERS, CODAGE ECHELONNABLE, ET TRANSMISSION ASYNCHRONE DANS UN TRANSFERT CONTINU DE DONNEES

(54) FILE SPLITTING SCALADE CODING AND ASYNCHRONOUS TRANSMISSION IN STREAMED DATA TRANSFER

(57)

Files (2750) are divided into parts (2716, 2718) and at least some of the parts are transmitted to a client using a communication channel. At least some of the transmitted parts are cached locally. This allows subsequent streaming playback of the file while using 'less bandwidth by transmitting the part of the file that hasn't been cached, and combining the cached parts with the tramitted parts. In some embodiments, files may be represented at a low quality level by a first data set (2804), and at higher quality levels with additional data sets (2806). Data sets are cached locally, so that during subsequent streaming playback of the file, the quality level of the playback may be improved by sending additional data sets using bandwidth that would otherwise be dedicated to transmitting the cached data sets.



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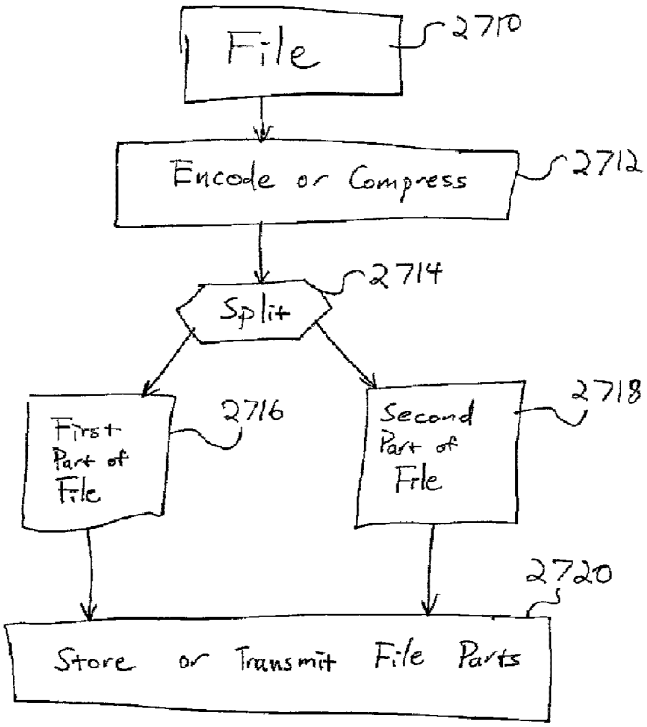
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(54) Titre : DECOUPAGE DE FICHIERS, CODAGE ECHELONNABLE, ET TRANSMISSION ASYNCHRONE DANS UN TRANSFERT CONTINU DE DONNEES

(54) Title: FILE SPLITTING SCALADE CODING AND ASYNCHRONOUS TRANSMISSION IN STREAMED DATA TRANSFER



(57) Abrégé/Abstract:
Files (2750) are divided into parts (2716, 2718) and at least some of the parts are transmitted to a client using a communication channel. At least some of the transmitted parts are cached locally. This allows subsequent streaming playback of the file while using 'less bandwidth by transmitting the part of the file that hasn't been cached, and combining the cached parts with the

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(57) Abrégé(suite)/Abstract(continued):
tramitted parts. In some embodiments, files may be represented at a low quality level by a first data set (2804), and at higher quality levels with additional data sets (2806). Data sets are cached locally, so that during subsequent streaming playback of the file, the quality level of the playback may be improved by sending additional data sets using bandwidth that would otherwise be dedicated to transmitting the cached data sets.

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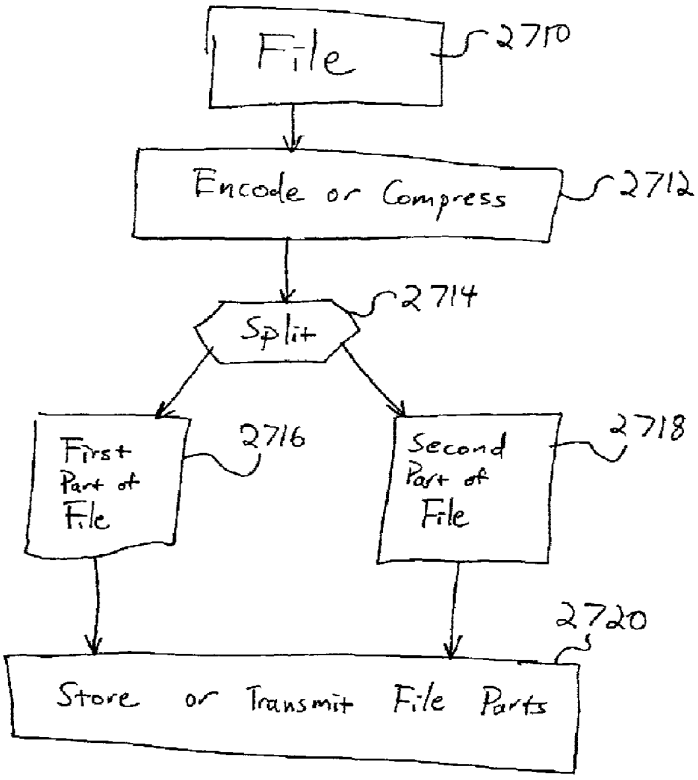
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[Continued on next page]

(54) Title: FILE SPLITTING SCALADE CODING AND ASYNCHRONOUS TRANSMISSION IN STREAMED DATA TRANSFER



(57) Abstract: Files (2750) are divided into parts (2716, 2718) and at least some of the parts are transmitted to a client using a communication channel. At least some of the transmitted parts are cached locally. This allows subsequent streaming playback of the file while using 'less bandwidth by transmitting the part of the file that hasn't been cached, and combining the cached parts with the tramitted parts. In some embodiments, files may be represented at a low quality level by a first data set (2804), and at higher quality levels with additional data sets (2806). Data sets are cached locally, so that during subsequent streaming playback of the file, the quality level of the playback may be improved by sending additional data sets using bandwidth that would otherwise be dedicated to transmitting the cached data sets.

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FILE SPLITTING, SCALABLE CODING, AND ASYNCHRONOUS TRANSMISSION IN STREAMED DATA TRANSFER

Cross-Reference to Related Application

[0001] This application is a continuation-in-part of U.S. Patent Application Serial Number 09/846,823, filed on April 30, 2001, Patent No. X,XXX,XXX, the disclosure of which is incorporated by reference, and which claimed priority from U.S. Provisional Application Serial Number 60/201,622, filed May 3, 2000, the disclosure of which is incorporated by reference. The present application also claims priority from provisional U.S. Patent Application Serial No. 60/337,939, for "File Splitting, Scalable Coding, and Asynchronous Transmission in Streamed Data Transfer," filed November 9, 2001, the disclosure of which is incorporated by reference.

Background of the Invention

Field of the Invention

[0002] The present invention is related to delivery of streamed programs such as audio and video, and more particularly to systems and methods providing improved control, efficiency, and quality of such streamed transmissions using file splitting, scalable coding, and asynchronous transmission.

Description of the Background Art

[0003] Delivery of audio and video programs over the Internet provides several advantages over conventional broadcast media such as radio and television. Unlike broadcast media, which require users to receive programs at particular times, or to record them for later use, Internet delivery allows users to select and receive programs upon demand, at a time that is convenient to them. For example, a user may browse to a news story, presented in text format, and click on a link that initiates playback of an audio report on the news item. Users may also click on links to hear songs or song samples, as is common in e-commerce sites, such as amazon.com or cdnow.com, in order to permit users to sample songs before purchasing compact discs (CDs). Internet delivery of audio programming may also be used for implementing personalized radio stations, which deliver music tracks selected in response to the tastes of particular users. Similar functionality is available for the delivery of video programs on demand, allowing users to view sports highlights, news reports, music videos, and even films and television shows, over the Internet.

[0004] Software for playing back such audio and video files is known in the art, including for example the Windows Media Player from Microsoft Corporation, and the RealPlayer from Real Networks, Inc. Functionality for audio and video delivery may also be built into browsers such as Netscape Navigator and Microsoft Internet Explorer.

[0005] One disadvantage of Internet delivery of audio and video programs is the relatively limited bandwidth that is available for any particular program. Compared with broadcast media, such as radio, television (over-the-air or cable), and the like, typical Internet connections offer far less bandwidth and thus limit the amount of information that may be transmitted to the end user in a given period of time. Thus, even with the application of aggressive compression algorithms, sound quality and picture quality of streamed programs received over the Internet tend to be substandard. For example, due to the limited number of bits available, existing Internet delivery schemes fail to provide received audio programs at a quality approaching that of CDs.

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[0006] As an alternative to streamed programs, and in order to improve quality of the received programs, users may download programs and then, subsequent to downloading them, play the received program via their computers. Since the program is not being viewed or listened to in "real time," more time is available to transmit and receive the program, so that larger files may be provided, and better quality achieved. However, it may take many minutes, or even hours, to download a short program at a reasonable level of quality. Thus, such a scheme does not provide the user with an immediate listening or viewing experience; rather, the user must wait until the program is downloaded before it can be viewed or listened to.

Summary of the Invention

[0007] The present invention provides improved quality, security, and efficiency for streamed programs, by combining received streamed data with previously-stored (cached) data. In one embodiment, a program file containing program data such as audio, video, or the like, is split into two or more sections. In one embodiment, each section is not usable on its own to provide program output (e.g., audio signals where the program file is an audio file), but can only be used when recombined with the remaining sections. In one embodiment, one section of the split data is considerably smaller than the other section(s). This splitting allows the second section to be cached by a client machine without a danger that the client has a persistent usable copy of the original file. This allows the benefits of caching to be realized without providing users with unauthorized persistent copies of files.

[0008] For example, the second section may be transmitted in advance of the actual playback of a program file, thus avoiding bottlenecks that may result when the entire program file is transmitted upon user demand. Until the first section is transmitted, the user will not be able to play the program file. The smaller first section may be streamed to allow playback of the program file. The first section is discarded after playback so that no persistent usable copy of the program file remains on the user's machine. The second section remains cached, allowing future streaming playback to be performed efficiently. The ability to not provide a persistent usable

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copy of the program file can be advantageous because copyright holders may not wish to authorize such persistent copies, since the persistent copy could cannibalize revenues from sales of the program file in a tangible medium (such as audio CDs), or paid future downloads, streamed or otherwise, of the program file.

[0009] Alternatively, the program file is split into sections in order to provide scalability in the playback quality level. The first section is playable at a relatively low quality level. Additional sections of data may be added to the first section to increase the quality level. Thus, the program file may be downloaded and played at a quality level determined by the bandwidth of the connection. The sections may be cached so that when it is desired to play the program file again, additional sections may be downloaded and added for higher quality playback.

[0010] In some embodiments, a persistent copy of a playable version of the program file is not stored on the client. The additional sections are not playable without the first level. Thus, the additional sections may be cached, so that the file can be played back by combining a downloaded first section with cached additional sections.

[0011] The file splitting and scalable coding embodiments may also both be used on the same program file. This allows most of the file to be cached while still providing the server control over when the file may be played back. It also allows subsequent playbacks of the file after the first to be progressively higher quality as more of the scalable sections are transmitted with every playback.

Brief Description of the Drawings

[0012] Fig. 1A is a block diagram of a functional architecture.

[0013] Fig. 2 is a block diagram of a conceptual architecture for one embodiment.

[0014] Figs. 3A and 3B illustrate a method for splitting a program file according to one embodiment of the present invention.

[0015] Figs. 3C and 3D illustrate a method of receiving and playing a previously split program file according to one embodiment of the present invention.

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[0016] Fig. 4A illustrates an example of a scalably-coded program file.

[0017] Fig. 4B is a block diagram illustrating the use and combination of primary data and secondary data to provide different playback quality levels.

[0018] Figs. 4C and 4D depict examples of scalable coding according to one embodiment of the present invention.

[0019] Figs. 5A and 5B depict techniques for combining file splitting and scalable coding according to one embodiment of the present invention .

Detailed Description of the Preferred Embodiments

[0020] The following description of preferred embodiments of the present invention is presented in the context of an Internet-based jukebox or personalized radio station where it is desirable to stream music files. One skilled in the art will recognize that the present invention may be implemented in many other domains and environments, both within the context of musical files, and in other contexts. Accordingly, the following description, while intended to be illustrative of a particular implementation, is not intended to limit the scope of the present invention or its applicability to other domains and environments. Rather, the scope of the present invention is limited and defined solely by the claims.

Architecture Overview

[0021] Referring now to Fig. 2, there is shown a conceptual architecture of one embodiment of the present invention. In the architecture of Fig. 2, the invention is implemented in connection with a web-based "jukebox" 103, or personalized radio station.

[0022] Stream delivery system 150 interacts with jukebox 103 to specify a sequence of audio files to deliver to jukebox 103. In some embodiments, this jukebox 103 may run on a client such as a personal computer, while the stream deliver server system is part of a remote server, connected to the client via a network. Jukebox 103 transmits requests to stream delivery system 150, and stream delivery system 150 delivers the audio files, as tracks, to jukebox 103. Stream delivery system 150 also communicates with real-time subscription authorization module 157, which includes real-

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time server 154 and database 156 that keep track of which user accounts are active and enforces global business rules about which accounts can listen to the radio at a given time. Within stream delivery system 150, there are a number of distinct software entities. Radio sequence generator 1613 receives requests from jukebox 103, receives format definitions 1611 and general constraints 1616, and receives recommendations from recommendation engine 107, to generate track selections to be transmitted to jukebox 103. The track selections generated by radio sequence generator 1613 specify which files to play according to estimated listener preferences as well as predetermined station formats. Authorization and content server 1614 keeps a record of the files that are selected by radio sequence generator 1613; server 1614 is consulted by radio sequence generator 1613 when files are requested. If generator 1613 does not provide the necessary security information, server 1614 flags this anomaly and declines to provide the data.

[0023] Referring now to Fig. 1A, there is shown a block diagram of a functional architecture for one embodiment of the present invention. Content index 110 provides a concise index of content stored in database 102, and is generated by conventional index generation means, to enable more efficient searching and updating of database 102.

Stream Delivery

[0024] In one embodiment, program files, such as audio files, are delivered to users as streamed data. The relationship discovery engine described in U.S. Patent Application Serial Number 09/846,823, filed on April 30, 2001, Patent No. X,XXX,XXX, describes one way to implement a personalized radio station, which may be used in conjunction with the present invention. The radio sequence transmitter 121 may deliver units of data to jukebox 103 in a format wherein each unit encodes a period of music. Since radio stations typically repeat their programming several times, it is beneficial to cache the data units in order to reduce the amount of transmitted data. In addition, if a sufficiently large time scale is used, different channels of the radio station may have considerable overlap among currently playing selections that are being delivered to various users. By identifying these common units, trans-

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mitter 121 can take advantage of further economies of transmission, so as to provide more efficient delivery of audio data.

[0025] In one embodiment, the transmitter 121 employs file splitting to improve the streaming performance, and provide streaming performance even in situations where channel capacity would otherwise be insufficient to provide the desired level of quality. In some embodiments, files are split prior to being stored in the content database 102 or with the compressed signal files 1615. In other embodiments, the files 101 are stored in the content database 102 or with the compressed signal files 1615 without first being split; the files are then split prior to being transmitted to a user for playback.

[0026] Fig. 3A is a flow diagram illustrating a method of splitting and storing a program file (such as a bitstream) containing program data such as audio, video, or the like, according to one embodiment. The process begins with the unsplit file 2710. Prior to being split, the file 2710 may be encoded and/or compressed 2712, although such operations are not essential to the present invention. Next the file 2710 is split 2714 into two or more parts, resulting in at least a first part 2716 of the file and a second part 2718 of the file. Particular techniques for splitting 2714 file 2710 are described in more detail in connection with Fig. 3B below. In one embodiment, the second part 2718 is substantially larger than the first part 2716. The file may be split 2714 into more than two parts. The parts 2716 and 2718 of the file 2710 are then stored 2720 in the content database 102 or with the compressed signal files 1615, or in some other location for later transmission. Alternatively, in an embodiment wherein files are split 2714 immediately prior to being transmitted, parts 2716 and 2718 are transmitted 2720 to an end user or remote computer for playback.

[0027] Fig. 3B is a block diagram illustrating an example of a method of splitting 2714 file 2710 into parts 2716, 2718 according to one embodiment. In the illustrated example, the file 2710 has M bits 2722-1 through 2722-M. The system generates first part 2716 of the file 2710 by taking N out of every P bits. The system generates second part 2718 of the file by taking the remaining P-N out of every P bits. In Fig. 3B, N is equal to one, and P is equal to four. Thus, the system assigns first bit 2722-1 to first part 2716, and assigns the next three bits 2722-2 through 2722-4 to sec-

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ond part 2718. The system then assigns fifth bit 2722-5 to first part 2716 and the next three bits 2722-6 through 2722-8 to second part 2718. The system repeats this pattern until all the bits of the file 2710 have been assigned to one of first and second parts 2716, 2718. In short, then, the system divides file 2710 into sections, with the first bit (or some other bit) of each section being sent to the first part 2716, and the remaining bits of each section being sent to the second part 2718. In general, the splitting technique of the present invention results in two or more sections 2716, 2718 each of which cannot be played back on its own, but can be played only when recombined with the other section or sections.

[0028] In one embodiment, N is equal to one, and P is equal to twenty, so that the first part 2716 is approximately 5% the size of the original file 2710, and the second part 2718 is approximately 95% the size of the original file 2710.

[0029] One skilled in the art will recognize that the system of the invention is not limited to file-splitting by bits, but may split files according to other units, such as bytes, or simply an arbitrary unit size. Alternatively, other file-splitting techniques may be used. For example, the system can include all headers, compression table selectors and scale factors into the first section 2716, and include all encoded program data (such as audio or video) into the second part 2718. Other methods of splitting the file 2710 into two or more parts may also be used.

[0030] In general, it is desirable in most embodiments that each part of the file 2710 is not decodable or able to be played back on its own, but can only be decoded and/or played back when recombined with the remaining part(s). This allows a part to be handled, transmitted, cached, or otherwise processed, without concerns that a user may permanently store and reuse an unauthorized copy of the program. Since a part cannot be used independently to recreate a recognizable facsimile of the signal in the original file 2710, the part can be cached by a client machine without any danger that the client has been given an unauthorized, useable persistent copy of the program file 2710. The ability to not provide a persistent usable copy of the program file can be advantageous because copyright holders may not wish to authorize such persistent copies, since the persistent copy could cannibalize revenues from sales of

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the program file in a tangible medium (such as audio CDs), or paid future downloads, streamed or otherwise, of the program file.

[0031] Fig. 3C is a flow diagram illustrating a method of receiving and playing a previously split program file according to one embodiment of the present invention. When a file is to be transmitted from stream delivery system 150 to the jukebox 103, the jukebox 103 or server 1614 determines 2724 whether the second part 2718 of the file 2710 has previously been stored, or cached, locally and is available for retrieval. If the second part 2718 is not available locally for retrieval, jukebox 103requests transmission of both parts 2716, 2718 of the file 2710. In response, server 1614 retrieves the requested parts 2716, 2718 from the files 1615 or the content database 102 (depending on where the parts 2716, 2718 have been stored), and transmits both the parts 2716, 2718 of the file 2710 to the jukebox 103, which receives 2726 them. Alternatively, if the files 2710 are stored unsplit, server 1614 retrieves the file 2710 to be sent, splits the requested file according to techniques described above, and then transmits the parts 2716, 2718 to the jukebox 103, which receives 2726 them.

[0032] Upon receiving 2726 parts 2716, 2718, in one embodiment the jukebox 103 stores 2732 the second part 2718 locally, so as to avoid the need to retransmit the second part 2718 if it is needed in the future. The jukebox 103 combines 2728 both parts 2716, 2718, and plays back 2730 the recombined program file 2710. This reception 2726, combination 2728, and playback 2730 may all take place concurrently, for example according to a streamed transmission methodology. In one embodiment, as the bits arrive at the jukebox 103, they are combined 2728 and played back 2730; the jukebox 103 need not wait until the entirety of the parts 2716, 2718 are received 2726 before combining 2728 and playing them back 2730. In one embodiment, the recombined file 2710 and the first part 2716 are discarded 2731 after or during playback. Since the cached second part 2718 represents only a portion of the program file 2710 and in one embodiment cannot be decoded or played back on its own, the invention prevents users from retaining an unauthorized playable copy of the program file 2710. Ultimate control over the user's playback of the program file 2710 thus remains with the server 1614, since the stored second part 2718 cannot be used to play back of the file 2710 until the server 1614 retransmits the first part 2716.

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[0033] If the second part 2718 has been received and stored locally in a prior session, jukebox 103 requests transmission of only the first part 2716 of the file 2710. In response, server 1614 retrieves the requested first part 2716 from the files 1615 or the content database 102, and transmits the first part 2716 to the jukebox 103, which receives 2734 it. Alternatively, if the files 2710 are stored unsplit, server 1614 retrieves the file 2710 to be sent, splits the requested file according to techniques described above, and then transmits the first part 2716 of the file 2710 to the jukebox 103, which receives 2734 it. The jukebox 103 retrieves 2736 the second part 2718 from local storage and combines 2738 the first and second parts 2716, 2718 to reconstruct the file 2710. The jukebox 103 plays back 2740 the reconstructed program file 2710. In one embodiment, as the bits arrive at the jukebox 103, they are combined 2738 with the stored second part 2718 to form a representation of the program file and played back 2740; the jukebox 103 need not wait until the entirety of the first part 2716 is received 2734 before combining and playing back the program. In other words, playback 2740 may take place while the first part 2716 is being streamed. As described above, in one embodiment, the recombined file 2710 and the first part 2716 are discarded 2731 after or during playback.

[0034] As can be seen from the description above, it is not necessary to transmit the second part 2718 more than once. The second part 2718 can be stored locally after the first transmission, so that, in one embodiment, only the first part 2716 need be transmitted for subsequent streaming playback of the program file 2710. Since in some embodiments the stored second part 2718 is substantially larger than the first part 2716, the present invention greatly reduces bandwidth requirements for streaming playback of the program file 2710. After the second part has been stored locally 2732, even clients with slow connections may effectively stream the program file 2710. Thus, from the user's perspective, the program file 2710 appears to be streamed in a manner equivalent to conventional streaming.

[0035] In addition, the described file splitting may provide advantages in licensing distribution of programs for playback by users. The file splitting benefits the licensor because the user does not receive a persistent usable copy of the program file, and the server retains control of playback of the program file 2710. This is advan-

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tageous because in contexts where blanket licensing or compulsory licensing is available for providing streamed data, in audio programming for example, a persistent copy would cannibalize revenues from future licensed streamed data downloads, and lack of control would make collecting licensing revenues difficult. The file splitting benefits users who do not want to wait while a large file is transmitted and received before accessing the program file. By splitting the file and storing part locally, transmission of large and unwieldy amounts of data in real-time is unnecessary. The user has quick access to the program file, even if he or she is using a slow communication channel.

[0036] The present invention thus improves efficiency in the transmission of program files such as audio or video files, and helps avoids bottlenecks associated with conventional streaming techniques, while still providing control and security.

[0037] Fig. 3D is a flow diagram illustrating a method of receiving and playing a previously split program file according to one embodiment of the present invention, so as to provide improved streaming performance from a user's perspective, even if adequate bandwidth to stream the entire file 2710 is not available, through advance downloading of the second section 2718. For example, the second section 2718 may be transmitted in advance of the actual playback of an audio or video program in a first session, thus avoiding potential bottlenecks that may result when the entire program file 2710 is transmitted upon user demand according to streamed techniques. Advance transmission can be performed at off-peak times, thus avoiding bandwidth bottlenecks. This advance transmission can occur when the user is not actually listening to music, so as to facilitate improved usage of an otherwise idle network connection.

[0038] The jukebox 103 determines 2742 which program files are likely to be requested by a user, so that at idle times it can transfer data that is likely to be useful in the future. Such determination may be made, for example, by using the learned artist relationships described in U.S. Patent Application Serial Number 09/846,823, filed on April 30, 2001, Patent No. X,XXX,XXX, in order to "guess" which tracks the user is most likely to request in the future. Alternative methods of determination may also be used. In some embodiments, the files the user will likely want may be

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known, such as when the user listens to a personalized radio station, or tends to listen to a particular online radio station. Such radio stations often have a list of the files that will be streamed later. Thus, this list can be used to determine 2742 what files will be required.

[0039] After the jukebox 103 determines 2742 what files will likely be required, the jukebox 103 requests the second parts 2718 of the files at a time when the connection is idle, or when sufficient bandwidth exists to transmit files. The authorization and content server 1614 then transmits 2744 the requested second parts 2718 to the jukebox 103. The jukebox 103 locally stores 2746 the second parts 2718 to the files. At a later time, when a user requests that a program file 2710 be streamed, the jukebox 103 requests the first part 2716 of the program file 2710, as described above. In response, authorization and content server 1614 transmits 2748 the first part 2716. The jukebox 103 combines 2750 the received first part 2716 with the stored second part 2718 to form a representation of the file 2710 and plays back 2752 the representation of the file 2710. Such a technique permits higher-quality playback than would otherwise be available, by pre-transmitting a significant portion of the data needed for playing back the media program. As described above, in one embodiment, the recombined file 2710 and the first part 2716 are discarded 2754 after or during playback.

[0040] In one alternative embodiment, instead of transmitting 2744 the second parts 2718 over a network, the second parts 2718 may be stored on physical media (such as a compact disc or floppy disk). That physical media is then physically sent to the location of the jukebox 103, where it can act as a local storage device, or the second parts 2718 may be transferred from the physical media to desired local storage. Thus, even for slow network connections, or for very large files, the user may enjoy a streaming experience, while the server retains control of the program file.

[0041] In another embodiment, the file is further split according to circumstances surrounding its transmission. The stream delivery system 150 begins to transmit all or part of the program file, such as an audio file, to the jukebox 103. When the program file, or part of the program file is partially transmitted, transmission is stopped. This stop can occur because of a disconnection between the stream

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delivery system 150 and the jukebox 103, because a user wishes to stop transmission and use the bandwidth for other purposes (such as when skipping to the next streamed song in a personalized radio station), or other reasons. The partially transmitted section of the program file or part of the program file is stored locally. Then, at a later time, the rest of the program file or part of the program file is transmitted and combined with the stored part. Such a process is more efficient than starting to transmit the entire program file or part of the program file from the beginning if it was not completely transmitted in a prior session.

[0042] In one embodiment, the size of the transmitted information is used to determine whether the entire file or section has been transmitted, and if not, what further information must be transmitted. At the beginning of transmission, the stream delivery system 150 sends information to the jukebox 103 indicating the size of the file and parts to be transmitted. This information may be sent to the jukebox 103 in other ways as well, as part of a sequence listing, for example. The jukebox 103 can then use the received size of the file in conjunction with the stored file size to determine what remaining information is needed from the stream delivery system 150. Other methods to identify what further information is needed to complete a partially received file may also be used.

[0043] For example, one embodiment splits a 1000 byte audio file into two parts, a first section 2716 of 50 bytes, and a second section 2718 of 950 bytes. The stream delivery system 150 transmits 800 bytes of the second section 2718 to the jukebox 103. At this point, a user chooses to start transmission of another audio file, and end transmission of the first audio file. The transmitted 800 bytes of the second section 2718 are stored locally. Thus, to allow the user to listen to the first audio file in its entirety, only the remaining 150 bytes of the second part 2718 need be transmitted to the jukebox. This subsequent transmission of the remaining 150 bytes may be done as needed, such as when a user begins to listen to the audio file again and the first 800 bytes are taken from local storage, then the last 150 bytes are received from the stream delivery system. This transmission can also be performed in advance of the time the user wishes to listen to the audio file, such as a scheme where the jukebox 103 periodically checks for partial file sections, such as partial second parts 2718, and auto-

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matically request transmission of the rest of the second part 2718. The jukebox 103 may identify partial file sections by comparing the total file size to the stored size, and then requesting only the missing information, or through other methods.

[0044] In another alternative embodiment, instead of discarding the first part 2716, the jukebox 103 encrypts the first part 2716 and stores the first part 2716 locally. This further reduces the amount of data that must be transmitted for program file 2710 playback. The server 1614 may still retain control over playback of the program file 2710 by controlling when the jukebox 103 may decrypt the first part 2716, for recombination with the second part 2718 and playback of the program file 2710. The second part 2718 could also be encrypted in place of, or in addition to, the first part 2716.

[0045] In yet another embodiment, transmitter 121 employs scalable coding to increase the quality of audio output despite limitations in channel capacity. Fig. 4A is a block diagram illustrating an example of a scalably-coded program file, including data stored in two sections 2804, 2806 that together form a program file 2802. Primary set of data 2804 is sufficient to play back the program file 2802 at a low quality level. Secondary set of data 2806 may be added to the primary set 2804 for higher-quality playback. The sets of data 2804, 2806 may be stored separately in the content database 102 or with the signal files 1615, or may be stored in a combined state, to be separated and transmitted as needed.

[0046] Fig. 4B is a block diagram illustrating the use and combination of primary data 2804 and secondary data 2806 to provide different playback quality levels. As mentioned above, the primary data 2804 is sufficient to play back the program file 2802 at a low quality level 2808. In one embodiment, the secondary data 2806 alone does not provide information sufficient for playback 2810 of the program file 2802. However, when the secondary data 2806 is combined 2812 with the primary data 2804, the combined data 2812 is sufficient to play back the program file 2802 at a high quality level 2814. For example, if the program file 2802 is an audio file, low-quality audio can be produced using the primary data 2804. Audio cannot be produced with secondary information 2806 alone. If secondary information 2806 is combined with the primary information 2804, output quality is enhanced. In one em-

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bodiment, additional levels of information may also be provided, each of which can be combined with the lower levels to further enhance output quality. This allows caching of lower-quality audio received in a first session and later receiving secondary information 2806 in a second session, which enables the jukebox 103 to combine the primary and secondary information to output audio of increased quality.

[0047] Since different sets of data are available that successively improve program file 2802 quality level, the quality of the output by the jukebox 103 depends on how much data can be transmitted in the time available. The first time an audio track is transmitted, transmitter 121 provides jukebox 103 with the primary information 2804 first, which allows the jukebox 103 to playback a representation of the program file 2802. Secondary 2806 (and additional) information is transmitted to allow improved quality levels as time permits. Jukebox 103 outputs the audio track with whatever level of information it has received at the time output is to commence. If only primary information 2804 has been received, jukebox 103 outputs lower-quality audio. If secondary information 2806 has also been received, it is combined with the primary information 2804 and jukebox 103 outputs higher-quality audio.

[0048] In addition, jukebox 103, in one embodiment, caches the received information. If the same audio track is requested at a later time, transmitter 121 provides jukebox 103 with the next level of information. Therefore, even if jukebox 103 was unable to provide higher-quality audio during the first listening, it may be able to provide higher-quality audio during subsequent listenings, by combining secondary (and/or additional) information with the previously cached primary information to generate the higher-quality audio output. Such a technique facilitates the output of high quality audio even when network transmission capacities are limited.

[0049] Referring now to Fig. 4C, there is shown an example of a transfer sequence for a channel with moderate bandwidth. Initially, tracks A and B are requested. Primary information for track A 2820 is downloaded. As primary information 2820 is downloaded, a low-quality representation of track A 2828 is played, according to conventional streaming audio techniques. Downloaded primary information 2820 is cached.

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[0050] Once the download of primary information for track A 2820 is complete, jukebox 103 begins to download primary information for track B 2822. This download may begin even though track A is still playing 2828. In the example shown in Fig. 4C, the download of primary information for track B 2822 is completed while track A is still playing 2828. Therefore, jukebox 103 begins to download secondary information for track B 2824. Then, when playback 2828 of track A is finished, jukebox 103 is able to output a high quality representation of track B 2830, by combining secondary information 2824 with previously downloaded primary information 2822. The output of the high quality version 2830 may take place while secondary information 2824 is still being downloaded, again using streaming techniques.

[0051] In the example of Fig. 4C, a request to play track A a second time is received. Therefore, once secondary information 2824 has been downloaded, jukebox 103 begins to download secondary information for track A 2826. Once the high quality version of track B 2830 is finished playing, jukebox 103 outputs a high quality representation of track A 2832, by combining secondary information 2826 with previously downloaded primary information 2820.

[0052] Referring now to Fig. 4D, there is shown another example of a transfer sequence for a channel with a lower bandwidth than that of Fig. 4C. Here, the secondary information for track B 2824 is not downloaded, because it would not arrive in time to improve the output of track B. Accordingly, a lower quality version of track B 2834 is output in lieu of the higher quality version 2830 of Fig. 4C. However, the higher quality version of track A 2832 can still be presented, since there is sufficient time to download secondary information for track A 2826 before the second playback of track A commences.

[0053] One skilled in the art will recognize that the tracks depicted in Figs. 4C and 4D may refer to individual songs, or song segments, or any other unit of information. One skilled in the art will further recognize that the scalable coding techniques described herein may be applied to video data, or to any other type of data, and are not limited to audio data.

[0054] The scalable coding techniques of the present invention thus facilitate the trading off of quality in bandwidth-limited situations, without requiring

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complex bandwidth estimation and determination. If insufficient bandwidth exists for the delivery of higher-quality versions, the system simply continues playing lower quality versions of tracks. No skipping, pausing, or other interruption of the audio stream is necessary. Jukebox 103 can determine whether to continue any particular transfer to improve the available quality or to download the next requested track, based on upcoming track selections. At any given moment, the next data segment to request can be determined by requesting the highest priority data segment from the next few audio segments. In one embodiment, priorities are defined to either play audio at a maximum short-term quality level or at a consistent quality level.

[0055] In one embodiment, jukebox 103 requests data for downloading according to the following order of priorities:

Priority	Type of value
1	Primary information, next track
2	Secondary information, next track
3	Primary information, track after next
4	Secondary information, track after next
5	Tertiary information, next track
6	Tertiary information, track after next
7	Data for subsequent tracks

[0056] One skilled in the art will recognize that any desired priority list may be provided. For example, if item 5 in this table is moved up to the third rank, the system will give more priority to high quality presentation at the possible expense of inconsistent quality on lower bandwidth connections.

[0057] In one embodiment, locally-cached downloaded data is stored in an encrypted or otherwise protected form, so as to prevent its abuse and to inhibit copyright infringement. In another embodiment, primary information is stored in an encrypted or otherwise protected form, but secondary and subsequent information is not, since the secondary and subsequent information is unusable without access to the primary information.

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[0058] In one embodiment, jukebox 103 downloads data sets when the user is not actually listening to music, so as to facilitate improved usage of an otherwise idle network connection. Jukebox 103 determines which items are likely to be requested by a user, so that at idle times it can transfer data that is likely to be useful for rendering audio segments in the future. Such determination may be made in the same way as described above with respect to the split files of Fig. 3D. In one embodiment, secondary information 2806 for such "predicted" audio segments is downloaded first, so that encryption is not required unless and until the user actually requests the tracks and the primary information 2804 is to be downloaded. Scalable coding may also be used to process a signal of a conventional broadcast radio station that plays music. An audio recognition device, as is conventional, pre-processes the signal in order to identify individual songs. Those portions of audio information that are not music are compressed and stored, and a transfer sequence is sent to jukebox 103 that references these recently encoded non-music segments as well as previously known and cached musical segments. The recently encoded segments can be encoded at a lower quality level in order to allow a jukebox 103 connected by a low speed line to transfer the recently encoded segments in real-time while still playing the cached musical segments at a higher quality level.

[0059] As with file splitting, portions of scalably coded files may also be sent on physical media rather than transmitted over a network. Similarly, if sections of scalably coded information are only partially transmitted, they may be stored locally, and then only the information not previously received is transmitted in a subsequent session.

[0060] File splitting and scalable coding may also be used in combination. Fig. 5A is a block diagram illustrating how a program file 2902 may be divided into primary data 2904 and secondary data 2906, and the primary data 2904 file split into a first part 2908 and a second part 2910. The primary data 2904 is split as described above with respect to Figs. 3A and 3B. This allows almost all of the primary data 2904 and secondary data 2906 to be cached locally without requiring encryption. Since, in one embodiment, the second part 2910 of the primary data 2904 is not playable without the first part 2908, and the secondary data 2906 is not playable without a playable

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set of primary data 2904, all of the program file 2902 except the first part 2908 of the primary data 2904 may be cached locally without providing the user with a usable copy of the program file 2902 that may be played back. This allows the server 1614 to retain control of playback of the program file 2902, as long as the first part 2908 of the primary data 2904 is not stored locally in a usable form.

[0061] Fig. 5B is a block diagram that illustrates how such a scheme provides advantages for streaming program files 2902. First, the first and second parts 2908, 2910 of the primary data 2904 are transmitted 2912 to the client by the server 1614. The first and second parts 2908, 2910 may be transmitted at roughly the same time in response to the jukebox 103 requesting the program file 2902. Alternatively, the second part 2910 may be transmitted in advance, after determination of what files 2902 are likely to be desired, as described above with respect to Fig. 3D. In an embodiment wherein the second part 2910 is transmitted in advance, the first part 2908 is transmitted in response to the jukebox 103 requesting the program file 2902. The first and second parts 2908, 2910 are sufficient to provide low quality playback 2914. The second part 2910 is then stored 2916 locally, and the first part 2908 is discarded. At a later time, such as when the jukebox 103 requests the program file 2902 again, the server 1614 transmits 2918 the first part of the primary data 2908 and the secondary data 2906. This allows sufficient information for the program file 2902 to be played back at a high quality level 2920. The secondary data 2906 is stored locally 2922, and the first part 2908 of the primary data 2904 is discarded. For subsequent playback of the program file 2902, only the first part 2908 of the primary data 2904 need be transmitted 2924 in order to enable high quality level playback 2920. Again, after such playback, the first part 2908 of the primary data 2904 is discarded, so that the server may retain control of program file 2902 playback. As an alternative to discarding the first part 2908, the first part 2908 may be encrypted, with decryption only occurring under the server's 1614 control.

[0062] Thus, a significant portion of the program file 2902 may be stored locally, with only the relatively small first part 2908 being transmitted from the server 1614 to provide the user with streaming file performance. This allows high quality streaming performance even over a relatively narrow bandwidth connection.

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[0063] As described above, when scalable coding or file splitting is used, the jukebox 103 plays back a representation of the program file. This representation may be an exact digital replica of the program file, such as when the program file is split, all parts are transmitted to the jukebox 103, and the entire file is combined for playback. The representation may also be a less than exact replica, such as when only some portions of a scalably coded program file are combined and played back.

Recommendation Engine

[0064] One method of determining in advance what program files a user may want streamed is through use of a recommendation engine, described more fully in U.S. Patent Application Serial Number 09/846,823, filed on April 30, 2001, Patent No. X,XXX,XXX. Note that there are also many other ways to determine what program files a user may want streamed in advance. Referring now to Fig. 2, the jukebox 103 or personalized radio station accepts a user's selections of music tracks and makes additional recommendations as to music tracks the user is likely to enjoy. The user is able to search for particular tracks and/or artists, and to control the playback of selected tracks. The system monitors the user's behavior with regard to searching, listening, and playback control, and generates and analyzes logs of such behavior in order to refine recommendations. Advertising, offers, and other information may be selected and presented to the user based on observations of user behavior and analysis as to which material may be of interest to the user.

[0065] Compressed signal files 1615 contain descriptions of music tracks, and in one embodiment contains digitized representations of the music tracks themselves. Compressed signal files 1615 are stored, for example, using conventional database storage means or in a conventional file system, and in one embodiment include several fields providing descriptive information regarding music tracks, such as title, album, artist, type of music, track length, year, record label, and the like.

[0066] Selected tracks are played via jukebox 103, which is implemented in one embodiment as a standalone application, or as a plug-in or bundled feature in browser 105. Jukebox 103 receives digitized representations of music tracks and plays the tracks over a speaker or headphones at the user's computer. In one embodiment,

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jukebox 103 can download and save music tracks in local storage (such as a hard disk drive, memory, or other local storage) in a compressed format, such as MP3, for playback on the user's computer or on a portable digital music listening device.

[0067] Recommendation engine 107 generates track preferences based on user information. Radio sequence generator 1613 uses track preferences, along with general constraints 1616 and format definitions 1611, to generate a sequence of tracks to be played. General constraints 1616 include particular rules and restrictions on the sequence of tracks, as may be required by law or as may be determined to be desirable for marketing or aesthetic purposes or for other reasons. Examples of constraints 1616 include: "no more than one song per hour from a particular album," or "do not play a fast song immediately after a slow song." Radio sequence generator 1613 may also incorporate a randomization element, if desired, and may be configurable by a website operator.

[0068] The track list is sent to jukebox 103 to be played to the user. A user activates jukebox 103 and selects music tracks for playback and/or purchase, via a user interface including controls and selectors. Authorization and content server 1614 checks that the appropriate security measures are in place (in order to prevent the user from "hacking" jukebox 103 to request unauthorized tracks from content server 1614), obtains the actual music tracks from files 1615, and provides them to jukebox 103 for output.

[0069] In one embodiment, the connections among the various elements of Figs. 1A and 2 are implemented over the Internet, using known protocols such as HTTP and TCP/IP. Secure sockets layer (SSL) or other encryption techniques may be employed for added security.

[0070] The recommendation engine may be employed in connection with conventional radio station programming techniques, to implement an improved personalized radio station. As is known in the art, conventional radio stations typically divide a programming block into a number of segments. Each segment is assigned a programming category, such as "power hit," "new release," "recurrent hit," and the like. For a particular programming block, music tracks are assigned to each of the segments based on the particular programming format of the radio station. Music

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scheduling software, such as Selector® by RCS Sound Software, applies heuristic rules for repetition limits and classes of songs, to automatically generate track lists for use by radio stations. The recommendation engine may be combined with such existing radio station programming techniques, to populate the defined segments with music tracks that are likely to appeal to a particular listener. Additional rules may be applied in generating track lists, so as to limit undesired repetition and to comply with limiting legislation (such as the Digital Millennium Copyright Act) and other restrictions.

[0071] From the above description, it will be apparent that the invention disclosed herein provides a novel and advantageous system and method for providing a user with a streaming program file experience. The foregoing discussion discloses and describes merely exemplary methods and embodiments of the present invention. As will be understood by those familiar with the art, the invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. For example, the invention may be applied to other domains and environments, and may be employed in connection with additional applications where personalized recommendations are desirable. Accordingly, the disclosure of the present invention is intended to be illustrative, but not limiting, of the scope of the invention, which is set forth in the following claims.

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[0072] What is claimed is:

1. In a client connected to a network and including a local storage device, a computer-implemented method of receiving and playing a media file comprising at least a first part and a second part, comprising:

receiving over the network and from a remote server in a first session the second part of the media file;

storing the second part at the local storage device;

receiving over the network and from a remote server in a second session subsequent to the first session the first part of the media file and not the second part of the media file;

combining the first part received in the second session with the stored second part after the start of the second session; and

playing a representation of the media file at the local client after combining at least part of the first and second parts after the start of the second session.

2. The computer-implemented method of claim 1, wherein the second part is not sufficient to properly play the representation of the media file back without being combined with the first part.

3. The computer-implemented method of claim 2, wherein the received parts of the media file are encoded, and the second part may not be decoded without being combined with the first part.

4. The computer-implemented method of claim 1, wherein the representation of the media file may not be played back at the local client without authorization by a remote server.

5. The computer-implemented method of claim 4, wherein authorization comprises the reception over the network and from a remote server the first part of the media file.

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6. The computer-implemented method of claim 1, wherein the neither the first part nor the second part may be used independently to recreate a recognizable facsimile of the content of the media file.

7. The computer-implemented method of claim 1, wherein the media file is divided into a plurality of sections, each section comprising a plurality of bits, wherein the first part comprises a first subset of bits from each section, and the second part comprises the remaining bits from each section.

8. The computer-implemented method of claim 1, wherein the media file is divided into a plurality of sections, each section comprising a plurality of bits, wherein the first part comprises a first bit from each section, and the second part comprises the remaining bits from each section.

9. The computer-implemented method of claim 7 or 8, wherein one of the sections contains exactly X bits, and wherein each of the remaining sections contains exactly Y bits, wherein X is less than or equal to Y.

10. The computer implemented method of claim 9, wherein Y equals 20.

11. The computer implemented method of claim 1, wherein the first part comprises headers, compression table selectors and scale factors of the media file.

12. The computer-implemented method of claim 1, further comprising:
receiving over the network and from a remote server during the first session the first part of the media file; and
playing the representation of the media file back at the local client during the first session.

13. The computer-implemented method of claim 1 or 12, wherein the first part is not stored at the local storage device after the playing of the media file.

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14. The computer-implemented method of claim 1 or 12, wherein the combined first and second parts are not stored at the local storage device after the playing of the media file.

15. The computer-implemented method of claim 1, wherein the played representation of the media file is an exact digital copy of the media file.

16. The computer implemented method of claim 1, wherein:

the media file further comprises a third part;

the first and second parts are combinable to form a representation of the media file at a first quality level; and

the first, second, and third parts are combinable to form a representation of the media file at a second quality level higher than the first quality level.

17. The computer implemented method of claim 16, further comprising:

receiving over the network and from a remote server the third part of the media file;

storing the third part at the local storage device;

combining the received third part with the stored first part and the stored second part to form the representation of the media file at the second quality level; and

playing the representation of the media file after combining the first, second, and third parts.

18. The computer implemented method of claim 17, wherein the third part is received over the network and from a remote server in a session other than the first session.

19. The computer implemented method of claim 17, wherein the third part and not the second part is received over the network and from a remote server in a session other than the first session.

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20. The computer-implemented method of claim 17, wherein the first part is not stored at the local storage device after the playing of the media file.

21. The computer-implemented method of claim 17, wherein the combined first, second, and third parts are not stored at the local storage device after the playing of the representation of the media file.

22. In a client connected to a network and including a local storage device, a computer-implemented method of receiving and playing a media file comprising at least a first part and a second part, comprising:

receiving over the network and from a remote server in a first session the first part of the media file, the first part of the media file a representation of the media file at a first quality level;

receiving over the network and from a remote server the second part of the media file, wherein the first and second parts are combinable to form a representation of the media file at a second quality level higher than the first quality level;

storing the second part at the local storage device;

receiving over the network and from a remote server in a second session subsequent to the first session the first part of the media file and not the second part of the media file;

combining the received first part with the stored second part; and

playing a representation of the media file at the local client.

23. The computer-implemented method of claim 22, wherein the first part is not stored at the local storage device after the playing of the media file.

24. The computer-implemented method of claim 22, wherein the representation of the media file is played after combining the first and second parts.

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25. The computer-implemented method of claim 22, wherein the representation of the media file is played in response to a command, and the representation of the media file is generated from at least the first part.

26. The computer-implemented method of claim 25, wherein the representation of the media file is generated from the second part as well as the first part if both the first part and the second part have been received at the time of playback.

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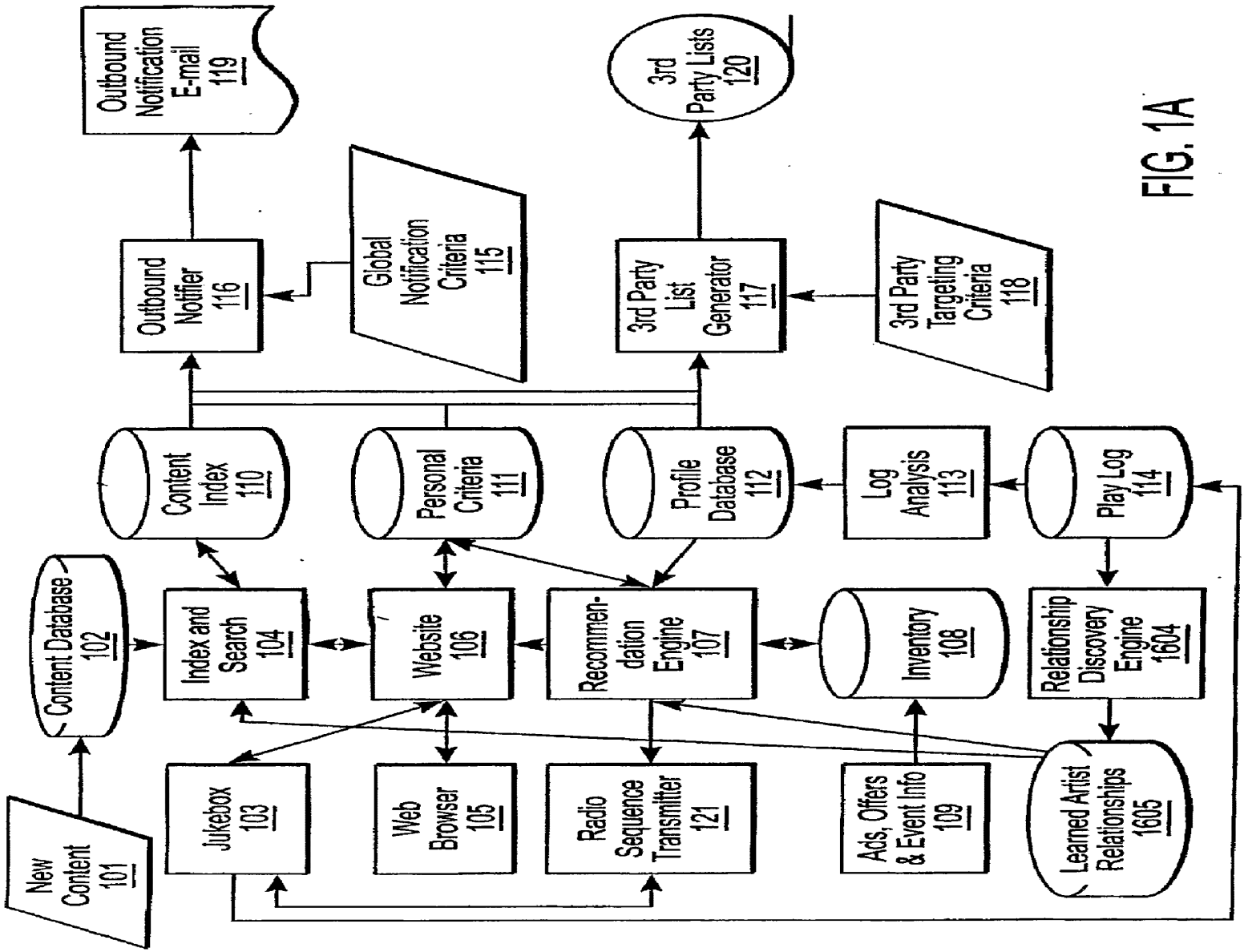


FIG. 1A

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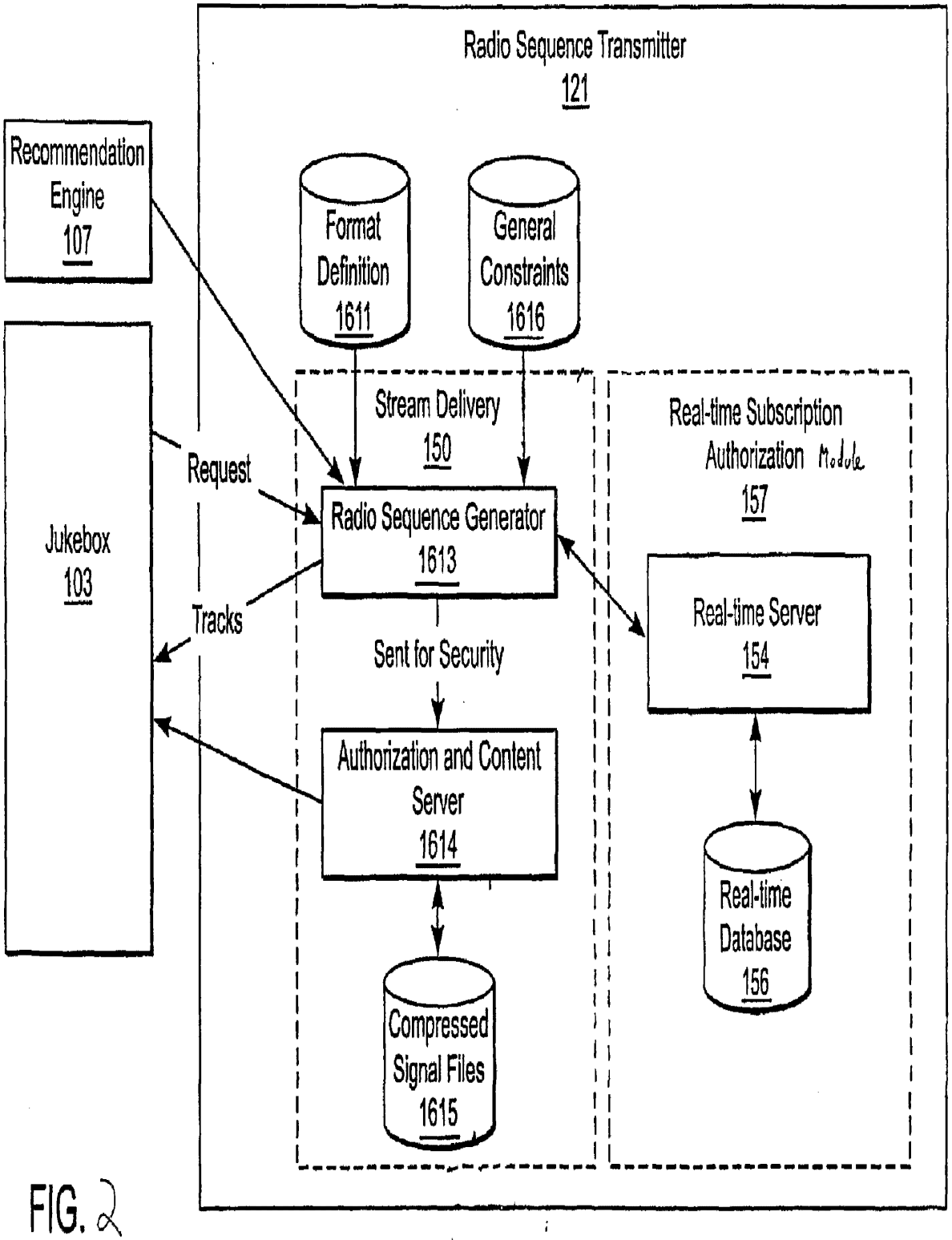

Radio Sequence Transmitter
121
Recommendation Engine
107
Format Definition
1611
General Constraints
1616
Stream Delivery
150
Real-time Subscription Authorization Module
157
Request
Radio Sequence Generator
1613
Jukebox
103
Tracks
Real-time Server
154
Sent for Security
Authorization and Content Server
1614
Real-time Database
156
Compressed Signal Files
1615

FIG. 2

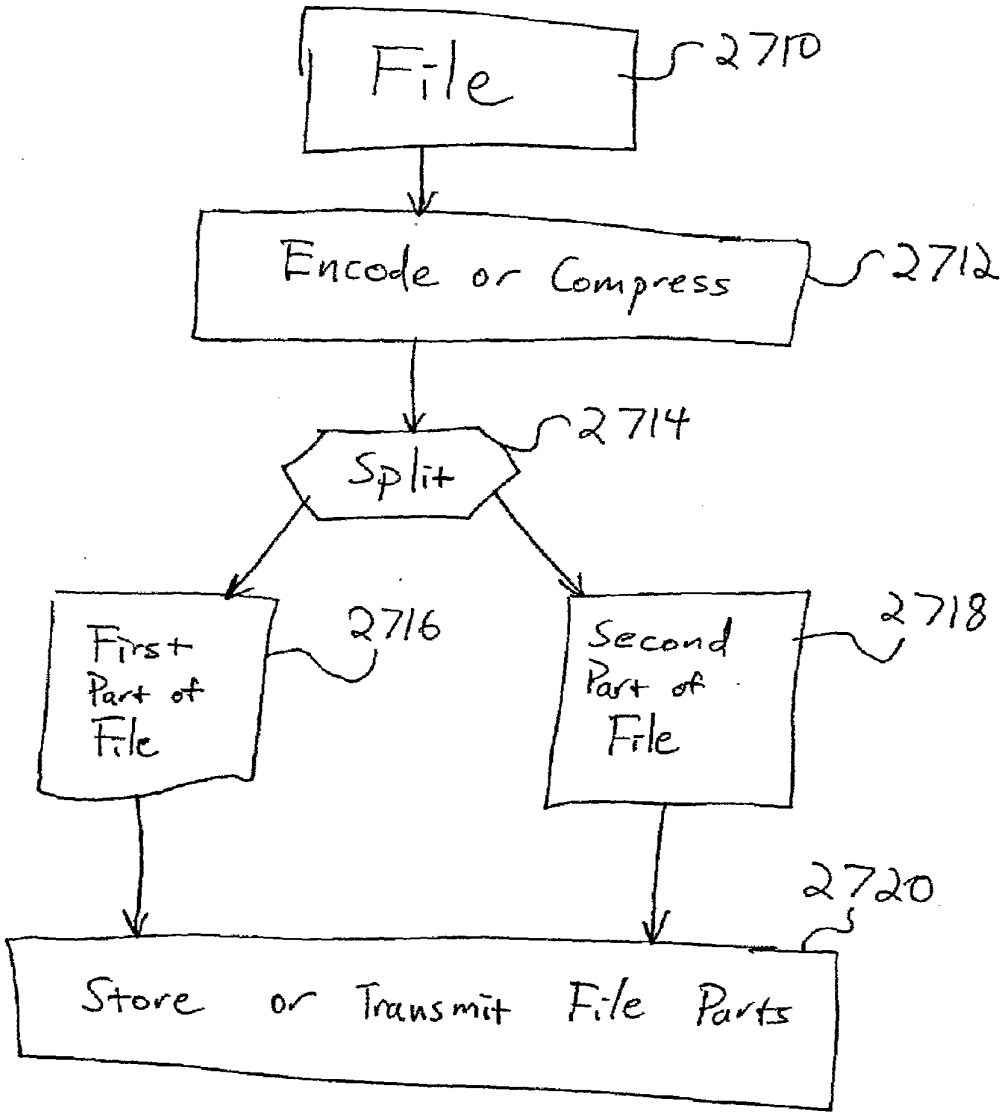

File
2710
Encode or Compress
2712
Split
2714
First Part of File
2716
Second Part of File
2718
Store or Transmit File Parts
2720

Fig. 3A

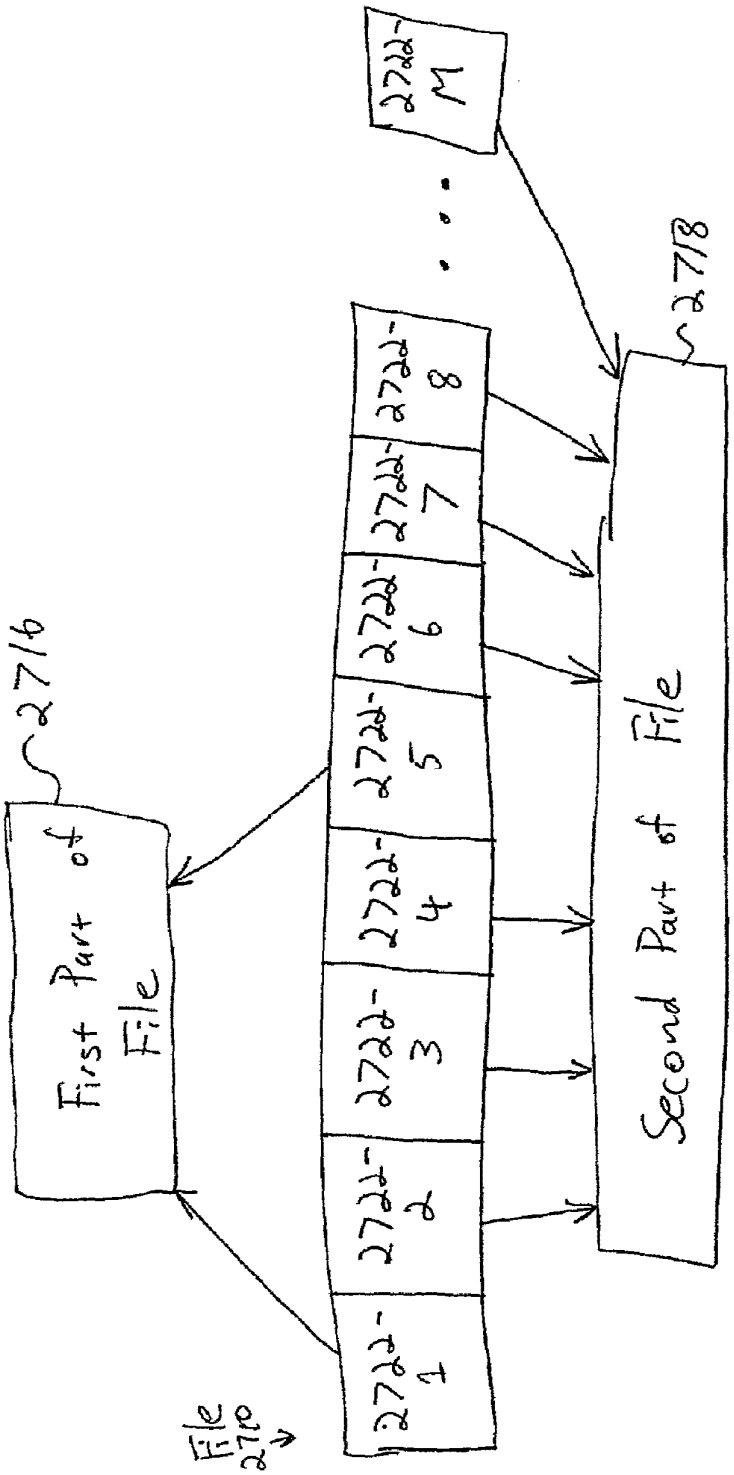

2722-1
2722-2
2722-3
2722-4
2722-5
2722-6
2722-7
2722-8
2722-M
2716
First Part of File
2718
Second Part of File
File 2720

Fig. 3B

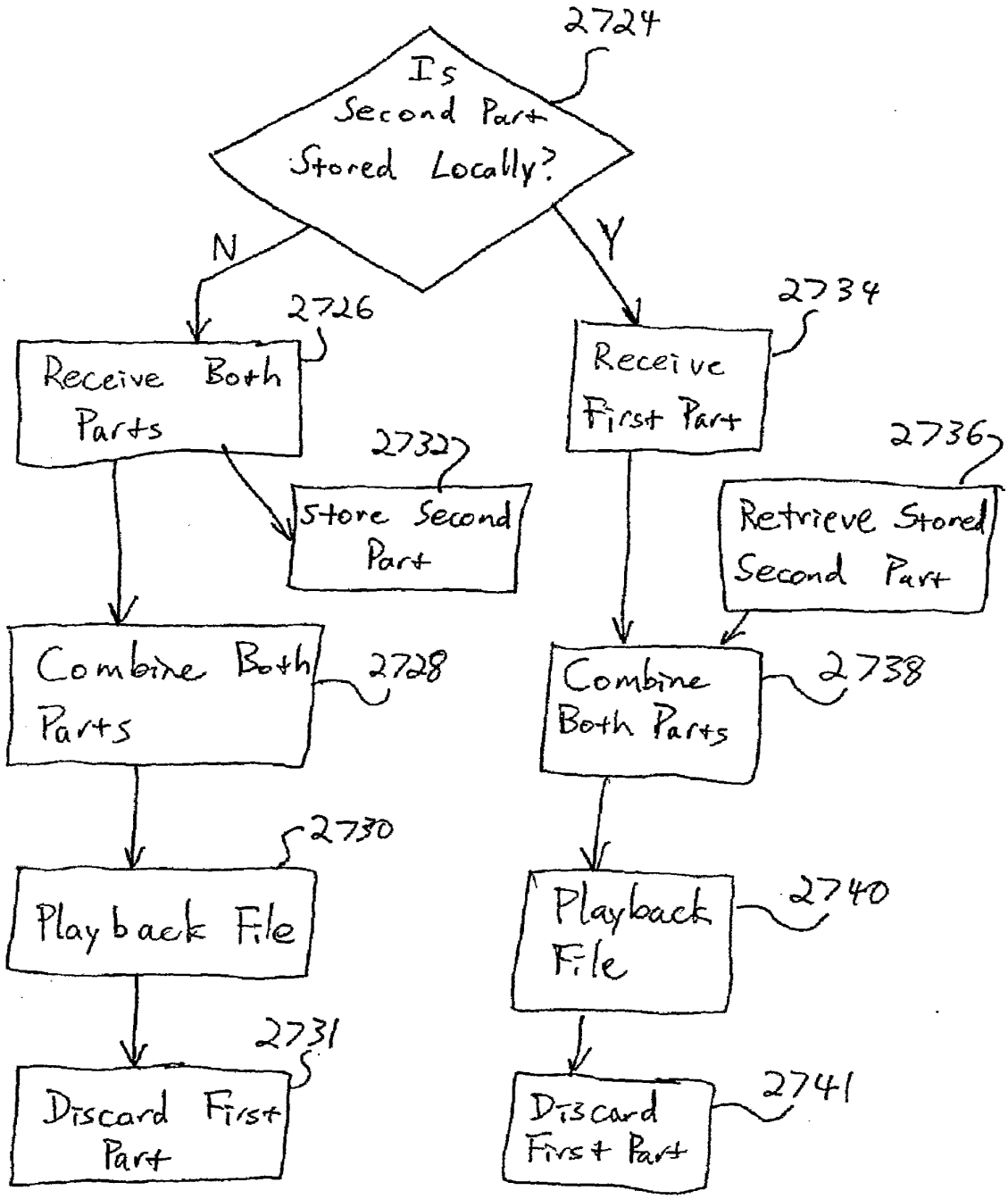

2724
Is Second Part Stored Locally?
N
Y
2726
Receive Both Parts
2732
Store Second Part
2734
Receive First Part
2736
Retrieve Stored Second Part
Combine Both Parts
2728
Combine Both Parts
2738
2730
Playback File
2740
Playback File
2731
Discard First Part
2741
Discard First Part

Fig. 3C

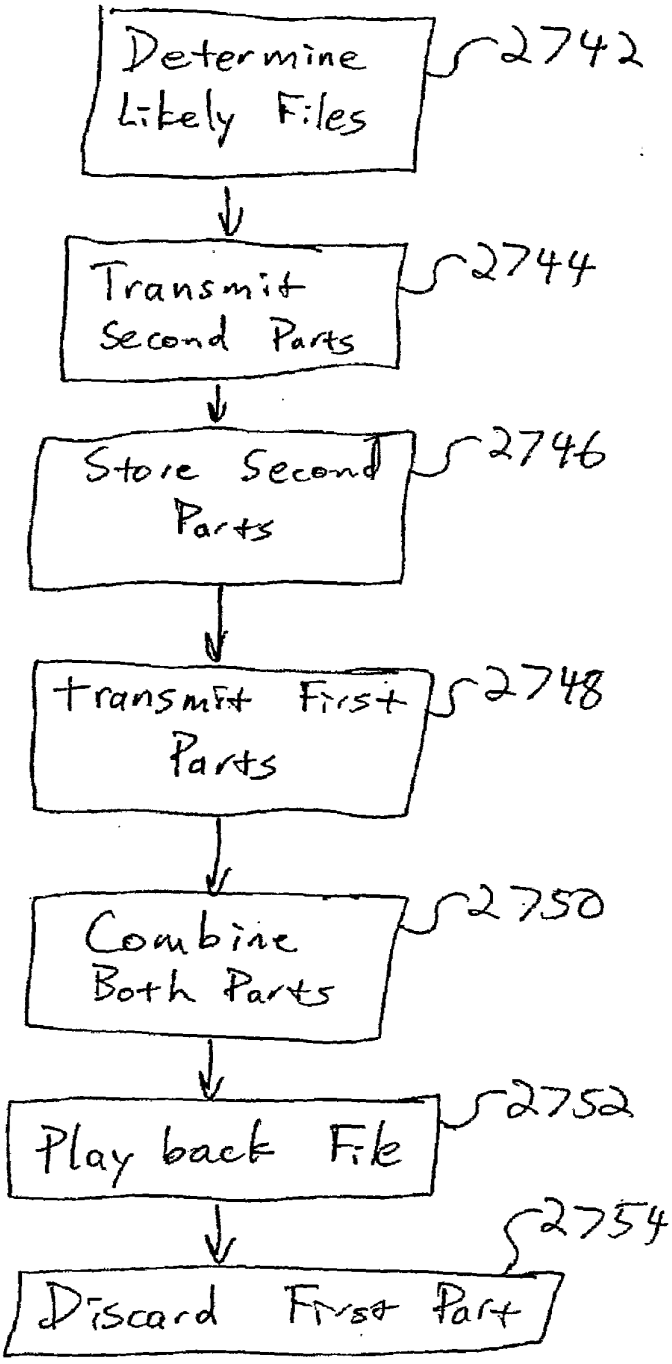
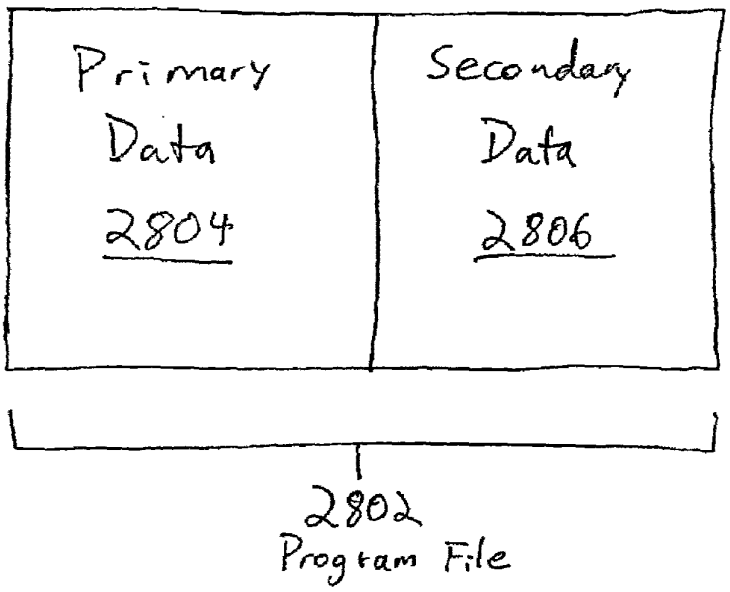

Determine Likely Files
2742
Transmit Second Parts
2744
Store Second Parts
2746
Transmit First Parts
2748
Combine Both Parts
2750
Play back File
2752
Discard First Part
2754

Fig. 3D

Fig. 4A


Primary Data 2804
Secondary Data 2806
2802 Program File

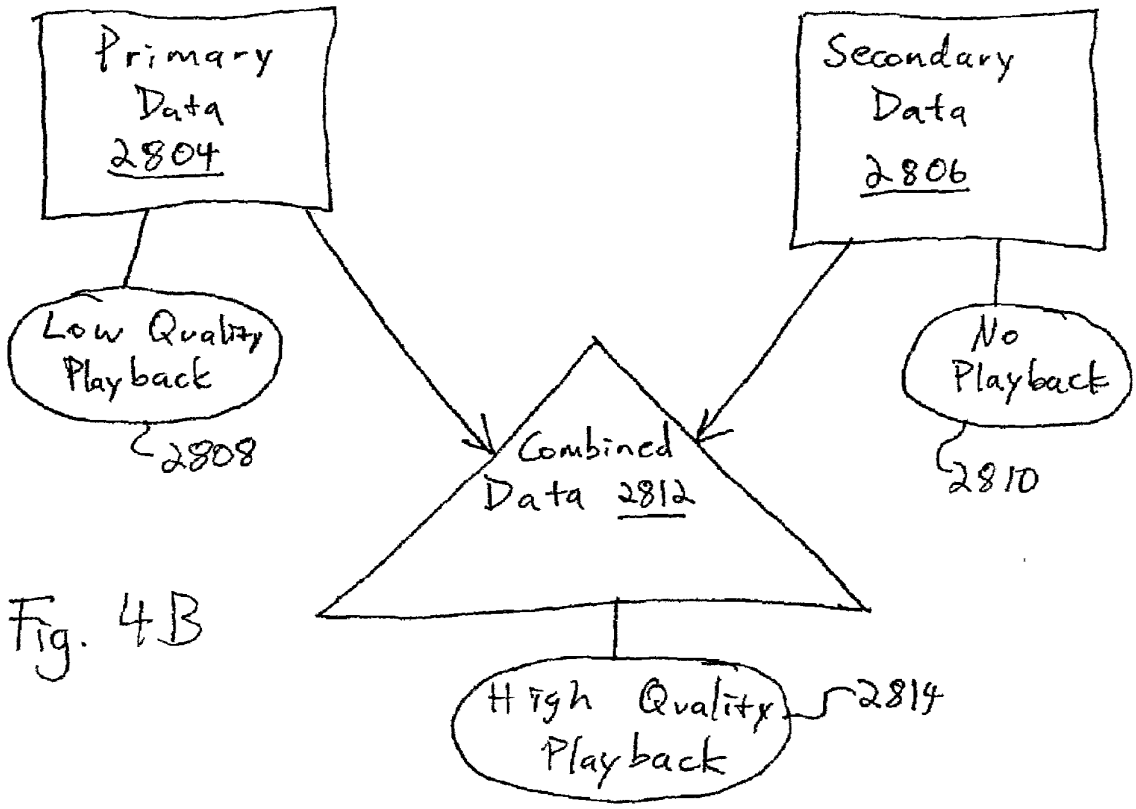

Primary Data 2804
Secondary Data 2806
Low Quality Playback
2808
Combined Data 2812
No Playback
2810
High Quality Playback
2814

Fig. 4B

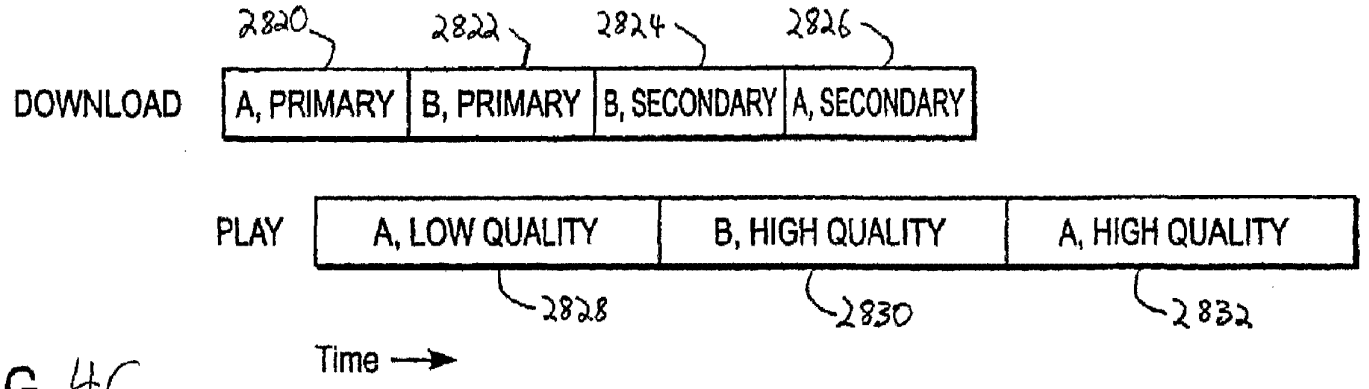


FIG. 4C

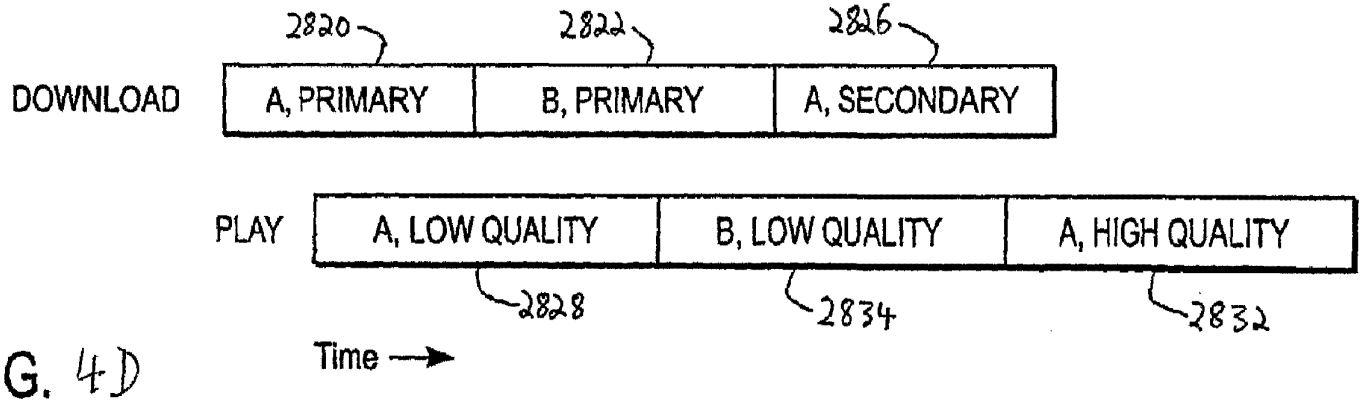


FIG. 4D

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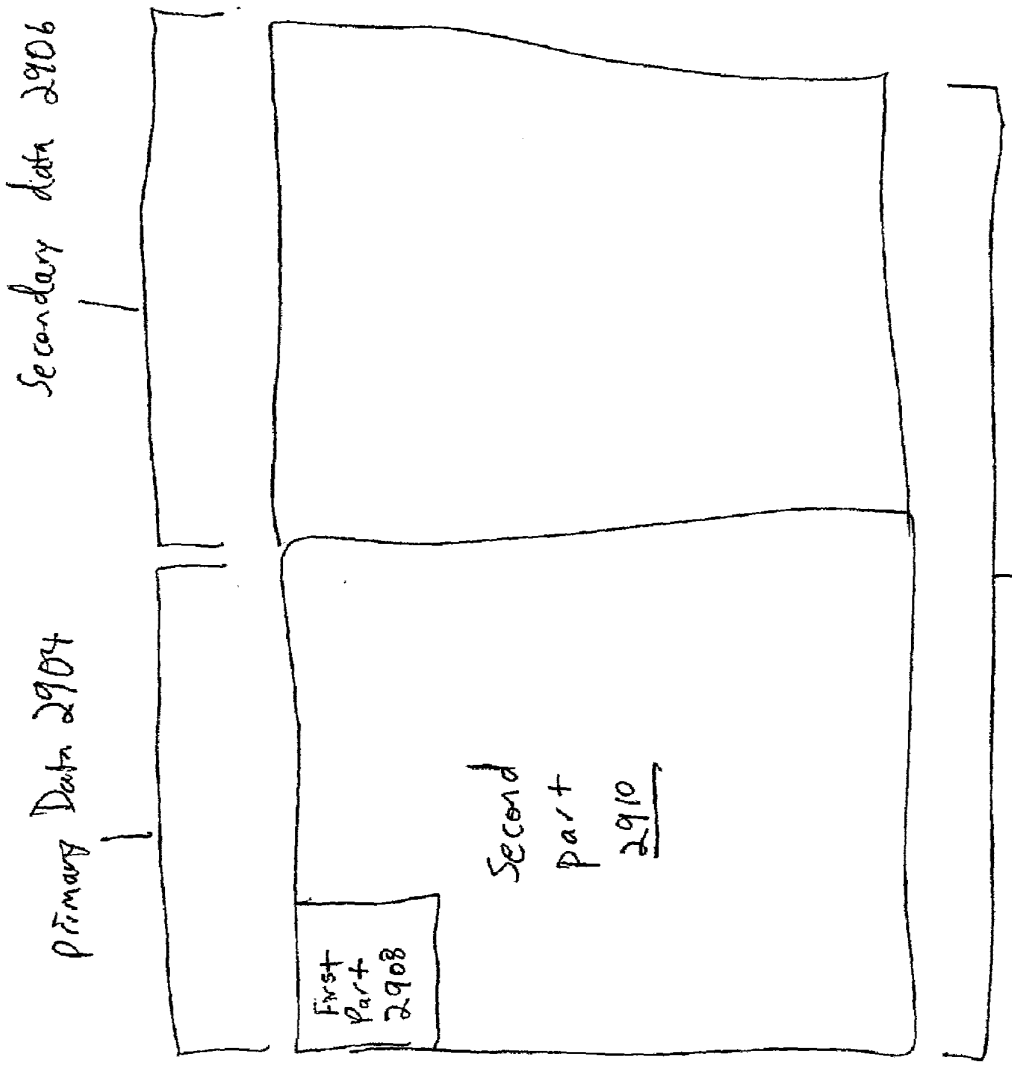

Secondary data 2906
Primary Data 2904
First Part 2908
Second Part 2910
Program File 2902

Fig. 5A

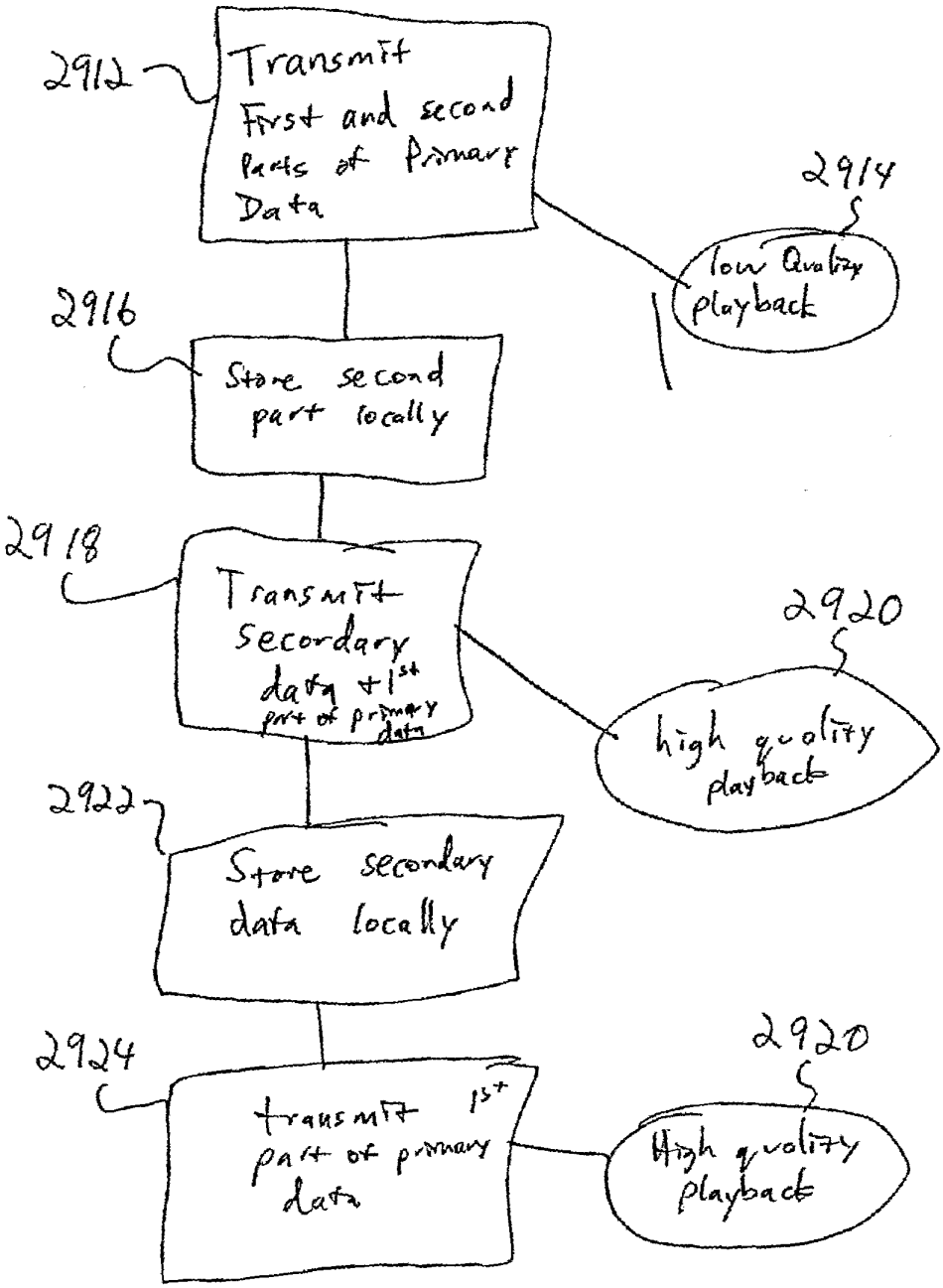


Fig. 5B

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IDS CERTIFICATION STATEMENTS

I. **THIS IDS IS BEING FILED UNDER 37 C.F.R. 1.97(b): (check one box)**

☐ Within three months of the filing date of a national application other than a continued prosecution application under 1.53(d).

☐ Within three months of the date of entry of the national stage as set forth in 1.491 in an international application.

☐ Before the mailing date of a first Office Action on the merits. In the event that a first Office Action on the merits has been mailed, please consider this IDS under 37 C.F.R. 1.97(c) and see the statement under 1.97(e) **or** charge deposit account 50-2091 the fee specified by 37 C.F.R. 1.17(p) if such statement is not selected in Section IV.

☐ Before the mailing of a first Office Action after the filing of a request for continued examination under 1.114.

II. **THIS IDS IS BEING FILED UNDER 37 C.F.R. 1.97(c):**

☑ After the period specified in 37 C.F.R. 1.97(b) and before the mailing date of any of a final action under 1.113, a notice of allowance under 1.311 or an action that otherwise closes prosecution in the application, and accompanied by:

- ☐ a statement specified in 1.97(e) as subsequently provided in this IDS; or
- ☑ the fee set forth in 1.17(p).

III. **THIS IDS IS BEING FILED UNDER 37 C.F.R. 1.97(d):**

☐ After the period specified in 37 C.F.R. 1.97(c) and on or after the mailing date of any of a final action under 1.113, a notice of allowance under 1.311 or an action that otherwise closes prosecution in the application, but before or simultaneous with payment of the issue fee, and accompanied by a statement specified in 1.97(e) as subsequently provided in this IDS **and** the fee set forth in 1.17(p).

IV. **Statement under 37 C.F.R. 1.97(e) (check only one box)**

The undersigned hereby states that:

☐ Each item of information contained in the IDS 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 this IDS.

☐ No item of information contained in the IDS was cited in a communication from a foreign patent office in a counterpart foreign application, and, to knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the IDS was known to any individual designated in 37 C.F.R. 1.56(c) more than three months prior to the filing of this IDS.

V. **Statement under 37 C.F.R. §1.704(d)**:

☐ The undersigned hereby states that each item of information contained in the information disclosure statement: (i) was first cited in any communication from a patent office in a counterpart foreign or international application or from the Office, and this communication was not received by any individual designated in § 1.56(c) more than thirty days prior to the filing of the information disclosure statement; or (ii) is a communication that was issued by a patent office in a counterpart foreign or international application or by the Office, and this communication was not received by any individual designated in § 1.56(c) more than thirty days prior to the filing of the information disclosure statement..

VI. **CONCLUSION**

It is respectfully submitted that the claims presently on file patently distinguish the present invention from each of the references cited in this IDS. The references cited in this IDS are being cited only in the interest of candor and without any admission that they constitute statutory prior art or contain matter which anticipates the invention or which would render the same obvious, either singly or in a combination, to a person of ordinary skill in the art. Furthermore the filing of this IDS should not be construed to be an admission that the information cited in this IDS is, or is considered to be, material to patentability as defined in 1.56(b). In addition, the filing of this IDS should not be construed as a representation that a search has been made.

If the Examiner has any questions concerning this IDS, the Examiner is requested to contact the undersigned at the telephone number associated with Customer No. 70560 . If it is determined that this IDS has been filed under the wrong rule, the PTO is requested to consider this IDS under the proper rule, with a petition if necessary, and charge the appropriate fee to Deposit Account No. 50-2091.

Electronic Acknowledgement Receipt

EFS ID:	36437296
Application Number:	16252188
International Application Number:	
Confirmation Number:	3722
Title of Invention:	APPARATUS, SYSTEM, AND METHOD FOR MULTI-BITRATE CONTENT STREAMING
First Named Inventor/Applicant Name:	DAVID F. BRUECK
Customer Number:	70560
Filer:	Brett Carlson/Julie Graf
Filer Authorized By:	Brett Carlson
Attorney Docket Number:	066.0141X1C7
Receipt Date:	27-JUN-2019
Filing Date:	18-JAN-2019
Time Stamp:	17:47:43
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Information Disclosure Statement (IDS) Form (SB08)	20190627_IDS-3_066-0141X1C7.pdf	614805 bb181cf19295a7c8f81a780648fbd37808b2a917	no	4

Warnings:

Information:					
2	Transmittal Letter	20190627_IDSCert_066-0141X1C7.pdf	227440 176ba1014fc671051cf91a994df4b3c9296caea5	no	1
Warnings:					
Information:					
3	Non Patent Literature	NPL_Bommaiah.pdf	427349 0120adb7c21f844fbbf72df8893e203595ba229e	no	11
Warnings:					
Information:					
4	Non Patent Literature	NPL_Roy.pdf	203211 6b2c4564d29af008372104a817676f18da1b87c8	no	4
Warnings:					
Information:					
			Total Files Size (in bytes):	1472805	

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New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a 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.

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	16252188
Filing Date	2019-01-18
First Named Inventor	David F. Brueck
Art Unit	2454
Examiner Name	Chirag R. Patel
Attorney Docket Number	066.0141X1C7

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
	1	5267334	A	1993-11-30	Normille et al.	
	2	5404446	A	1995-04-04	Bowater et al.	
	3	5841432	A	1998-11-24	Carmel et al.	

If you wish to add additional U.S. Patent citation information please click the Add button. Add

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Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20020156912	A1	2002-10-24	Hurst et al.	
	2	20030055995	A1	2003-03-20	Ala Honkola	

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FOREIGN PATENT DOCUMENTS Remove

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	16252188
	Filing Date	2019-01-18
	First Named Inventor	David F. Brueck
	Art Unit	2454
	Examiner Name	Chirag R. Patel
	Attorney Docket Number	066.0141X1C7

	1							

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NON-PATENT LITERATURE DOCUMENTS Remove

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	1	ROY, S., et al., "Architecture of a Modular Streaming Media Server for Content Delivery Networks," 2002 IEEE. Published in the 2003 International Conference on Multimedia and Expo ICME 2003.	☒
	2	BOMMAIAH, E., et al., "Design and Implementation of a Caching System for Streaming Media over the Internet," 2000 IEEE. Published in RTAS '00 Proceedings of the Sixth IEEE Real Time Technology and Applications Symposium (RTAS 2000), page 111.	☒

If you wish to add additional non-patent literature document citation information please click the Add button Add

EXAMINER SIGNATURE

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	16252188
Filing Date	2019-01-18
First Named Inventor	David F. Brueck
Art Unit	2454
Examiner Name	Chirag R. Patel
Attorney Docket Number	066.0141X1C7

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).

☒ See attached certification statement.

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

None

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)	2019-06-27
Name/Print	Brett A. Carlson	Registration Number	39928

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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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. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these record s.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

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Page 619

Document Description: Issue Fee Payment (PTO-85B)

Issue Fee Transmittal Form

Application Number	Filing Date	First Named Inventor	Atty. Docket No.	Confirmation No.
16252188	18-Jan-2019	DAVID BRUECK	066.0141X1C7	3722

TITLE OF INVENTION :

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

Entity Status	Application Type	Art Unit	Class - Subclass	EXAMINER
Regular Undiscounted	Utility under 35 USC 111(a)	2454	219000	CHIRAG PATEL

Issue Fee Due	Publication Due	Total Fee(s) Due	Date Due	Prev. Paid Fee
$1000	$0	$1000	13-Dec-2019	$0

1.Change of Correspondence Address and/or Indication Of Fee Address (37 CFR 1.33 & 1.363)

Current Correspondence Address:	Current Indicated Fee Address :
70560 LKGLOBAL (Dish Technologies L.L.C.) 7010 E. COCHISE ROAD SCOTTSDALE AZ 85253 UNITED STATES 480-385-5060 dish@lkglobal.com	
☒ Change of correspondence address requested, system generated AIA/122-EFS form attached	☒ Fee Address indication requested, system generated SB/47-EFS form attached

2.Entity Status

Change in Entity Status

○ Applicant certifying micro entity status; system generated Micro Entity certification form attached. See 37 CFR 1.29.
Note: Absent a valid certification of micro entity status, issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment. If this box is checked, you will be prompted to choose a micro entity status on the gross income basis (37 CFR 1.29(a)) or the institution of higher education basis (37 CFR 1.29(d)), and make the applicable certification online.

○ 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.

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Page 620

Document Description: Issue Fee Payment (PTO-85B)

3.The Following Fee(s) Are Submitted:

☒ Issue Fee	☐ I authorize USPTO to apply my previously paid issue fee to the current fees due
☐ Publication Fee	☐ The Director is hereby authorized to apply my previously paid issue fee to the current fee due and to charge deficient fees to Deposit Account Number _____
☐ Advance Order - # of copies _____	☒ If **in addition to** the payment of the issue fee amount submitted with this form, there are any discrepancies in any amount(s) due, the Director is authorized to charge any deficiency, or credit any overpayment, to Deposit Account Number 502091 . The **issue fee must be submitted** with this form. **If payment of the issue fee does not accompany this form, checking this box and providing a deposit account number will NOT be effective to satisfy full payment of the fee(s) due.**

4.Firm and/or Attorney Names To Be Printed

NOTE: If no name is listed, no name will be printed
For printing on the patent front page, list to be displayed as entered

1. LORENZ & KOPF LLP
2.
3.

5.Assignee Name(s) and Residence Data To Be Printed

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

Name	City	State	Country	Category
DISH Technologies L.L.C.	Englewood	COLORADO	united states	corporation

6.Signature

I certify, in accordance with 37 CFR 1.4(d)(4) that I am an attorney or agent registered to practice before the Patent and Trademark Office who has filed and has been granted power of attorney in this application. I also certify that this Fee(s) Transmittal form is being transmitted to the USPTO via EFS-WEB on the date indicated below.

Signature	/BRETT A. CARLSON/	**Date**	09-13-2019
Name	Brett Carlson	**Registration Number**	39928

Electronic Patent Application Fee Transmittal

Application Number:	16252188
Filing Date:	18-Jan-2019
Title of Invention:	APPARATUS, SYSTEM, AND METHOD FOR MULTI-BITRATE CONTENT STREAMING
First Named Inventor/Applicant Name:	DAVID F. BRUECK
Filer:	Brett Carlson/Julie Graf
Attorney Docket Number:	066.0141X1C7

Filed as Large Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
UTILITY APPL ISSUE FEE	1501	1	1000	1000
PUBL. FEE- EARLY, VOLUNTARY, OR NORMAL	1504	1	0	0
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
			Total in USD ($)	**1000**

Electronic Acknowledgement Receipt

EFS ID:	37157317
Application Number:	16252188
International Application Number:	
Confirmation Number:	3722
Title of Invention:	APPARATUS, SYSTEM, AND METHOD FOR MULTI-BITRATE CONTENT STREAMING
First Named Inventor/Applicant Name:	DAVID F. BRUECK
Customer Number:	70560
Filer:	Brett Carlson/Julie Graf
Filer Authorized By:	Brett Carlson
Attorney Docket Number:	066.0141X1C7
Receipt Date:	13-SEP-2019
Filing Date:	18-JAN-2019
Time Stamp:	13:48:59
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$1000
RAM confirmation Number	E20199CD48564902
Deposit Account	
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Issue Fee Payment (PTO-85B)	Web85b.pdf	46440 942cf867709bdea7e061f7583394bb66e2d227d2	no	2
Warnings:					
Information:					
2	Change of Address	web85correspondenceaddress.pdf	37018 9f351f34fa1272a8f442d944214a75aaa7236a6c	no	1
Warnings:					
Information:					
3	Maintenance Fee Address Change	web85feeaddress.pdf	32652 345dc209a3f70fd0c18808125caef7963f324d4a	no	1
Warnings:					
Information:					
4	Fee Worksheet (SB06)	fee-info.pdf	31901 f0aee9b76fb459d341ee550727a7fe18fa03377c	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	148011		

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 a 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.

FEE ADDRESS INDICATION FORM

Application Number	16252188	Art Unit	2454
Filing Date	18-Jan-2019	Examiner Name	CHIRAG PATEL
First Name Inventor	DAVID BRUECK	Attorney Doc. Number	066.0141X1C7

INSTRUCTIONS: In order for the fee address identified on this form to be effective, the issue fee must have been paid for the application listed on this form. 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. For more information on customer numbers, see the Manual of Patent Examining Procedure (MPEP) § 403.

Please recognize as the Fee Address under the provisions of 37 CFR 1.363 the address associated with:

Customer Number:	000197 CPA GLOBAL LIMITED 2318 Mill Road 12th Floor ALEXANDRIA VA 22314 UNITED STATES 7037392234

Signature :

I certify, in accordance with 37 CFR 1.4(d)(4) that I am an attorney or agent registered to practice before the Patent and Trademark Office who has filed and has been granted power of attorney in this application.

Signature	/BRETT A. CARLSON/	**Date**	09-13-2019
Name	Brett Carlson	**Registration Number**	39928

CHANGE OF CORRESPONDENCE ADDRESS
Application

Application Number	16252188	Art Unit	2454
Filing Date	18-Jan-2019	Examiner Name	CHIRAG PATEL
First Name Inventor	DAVID BRUECK	Attorney Doc. Number	066.0141X1C7

Please change the correspondence address for the above-identified patent application to:

☒ The address associated with Customer Number:	54583 DISH Technologies L.L.C. 9601 S. Meridian Blvd ENGLEWOOD CO 80112 UNITED STATES 303-706-4506 ipdept@echostar.com

OR

☐ Firm or Individual Name:					
Address					
City		State		Postal Code	
Country					
Telephone		Email			

Signature :

I certify, in accordance with 37 CFR 1.4(d)(4) that I am an attorney or agent registered to practice before the Patent and Trademark Office who has filed and has been granted power of attorney in this application.

Signature	/BRETT A. CARLSON/	**Date**	09-13-2019
Name	Brett Carlson	**Registration Number**	39928

WEB C.AD 1.0

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S1	7	(("9998516") or ("9571551") or ("9071668") or ("8612624") or ("8402156") or ("7818444") or ("8868772")).PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2019/03/12 11:12
S2	1	("20180295174").PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2019/03/12 11:26
S3	0	(("("8880721" | "20030093790" | "8686066" | "8683066" | "20080120330" | "9344496" | "20050262257" | "9462074" | "7925781" | "8683066" | "6757796" | "20050262257" | "6389473" | "6708213" | "20080120330" | "20080120342" | "7925781" | "20110307545" | "20030093790" | "20080120342" | "9344496" | "8686066" | "20030236904" | "20110307545" | "8880721" | "20020087717").PN.").PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2019/03/12 12:07
S4	2	(("20050055425") or ("7369610")).PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2019/03/12 12:10
S5	68	encod$3 near3 stream with "600" near kbps	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/12 12:22
S6	11587	scalable near2 video near2 cod$3	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/12 12:27
S7	11587	scalable near2 video near2 cod$3 AND @AD<"200400430"	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/12 12:28
S8	525	scalable near2 video near2 cod$3 AND @AD<"20040430"	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/12 12:28
S10	282	enhancement adj layer AND bit-rate with encod$3	US-PGPUB; USPAT; USOCR;	OR	ON	2019/03/12 12:41

			FPRS; EPO			
S11	233	enhancement adj layer AND bit-rate with encod$3 and mpeg	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/12 12:42
S12	23	enhancement adj layer AND bit-rate with encod$3 and mbps	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/12 13:14
S13	23	("8880721" | "20030093790" | "8686066" | "8683066" | "20080120330" | "9344496" | "20050262257" | "9462074" | "7925781" | "8683066" | "6757796" | "20050262257" | "6389473" | "6708213" | "20080120330" | "20080120342" | "7925781" | "20110307545" | "20030093790" | "20080120342" | "9344496" | "8686066" | "20030236904" | "20110307545" | "8880721" | "20020087717").PN.	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/13 12:37
S14	1	("7818444").PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2019/03/14 12:22
S15	0	client near3 request with enhancement near2 layer with switch$3 with bit-rate	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 12:37
S16	9	client with scalable with video with switch$3	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 12:40
S17	23	scalable near2 video near2 cod$3 WITH STREAM AND @AD< "20040430"	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 12:40
S18	9	((H04N19/34 OR H04N19/40 OR H04N21/234327).CPC.) AND client near2 request with streamlet	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 12:41
S19	60	((H04N19/34 OR H04N19/40 OR H04N21/234327).CPC.) AND switch$3 with enhancement near2 layer	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 12:41
S20	8	((H04N19/34 OR H04N19/40 OR H04N21/234327).CPC.) AND request with	US-PGPUB;	OR	ON	2019/03/14 12:42

		switch$3 with enhancement near2 layer	USPAT; USOCR; FPRS; EPO			
S21	118	((H04N19/34 OR H04N19/40 OR H04N21/234327).CPC.) AND request with enhancement near2 layer	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 12:42
S22	25	((H04N19/34 OR H04N19/40 OR H04N21/234327).CPC.) AND request with enhancement near2 layer and @ad<"20040430"	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 12:44
S23	0	((H04N19/34 OR H04N19/40 OR H04N21/234327).CPC.) AND live same chunk$3 and @ad<"20040430"	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 14:10
S24	5	((H04N19/34 OR H04N19/40 OR H04N21/234327).CPC.) AND live and (streamlet chunk$3) and @ad<"20040430"	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 14:11
S25	1	((H04N19/34 OR H04N19/40 OR H04N21/234327).CPC.) AND live and (streamlet chunk$3) and enhancement AND @ad<"20040430"	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 14:12
S26	1	((H04N19/34 OR H04N19/40 OR H04N21/234327).CPC.) AND live NEAR STREAM and ENHANCEMENT adj layer and @ad<"20040430"	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 14:15
S27	4	((H04N19/34 OR H04N19/40 OR H04N21/234327).CPC.) AND real near2 time with chunk$3 and @ad<"20040430"	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 14:19
S28	4	enhancement near2 layer AND live and (streamlet chunk$3) and @ad<"20040430"	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 14:21
S29	36	((H04N19/34 OR H04N19/40 OR H04N21/234327).CPC.) AND timeline and @ad<"20040430"	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 15:23
S30	1	((H04N19/34 OR H04N19/40 OR H04N21/234327).CPC.) AND timeline and	US-PGPUB;	OR	ON	2019/03/14 15:23

		enhancement adj layer AND @ad<"20040430"	USPAT; USOCR; FPRS; EPO			
S31	8	timeline SAME enhancement adj layer AND @ad<"20040430"	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 15:28
S32	0	((H04N19/34 OR H04N19/40 OR H04N21/234327).CPC.) AND VIRTUAL ADJ timeline and @ad<"20040430"	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 15:41
S33	9	timeline same playback AND enhancement adj layer AND @ad<"20040430"	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 15:59
S34	13	timeline same playback same playlist AND @ad<"20040430"	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 16:25
S35	0	timeline same playback same playlist AND scalable AND @ad<"20040430"	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 16:25
S36	5	timeline same playback same playlist AND enhancement AND @ad<"20040430"	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 16:25
S37	1	((H04N19/34 OR H04N19/40 OR H04N21/234327).CPC.) AND delay near2 "10" near2 second and @ad<"20040430"	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 19:54
S38	0	enhancement near2 layer AND live same sports and (streamlet chunk$3) and @ad<"20040430"	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 20:04
S39	394	live same sports and (streamlet chunk$3) and @ad<"20040430"	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 20:04
S40	0	scalab$3 near2 video AND live same sports and (streamlet chunk$3) and	US-PGPUB;	OR	ON	2019/03/14 20:04

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S41	2	scal$3 near2 video AND live same sports and (streamlet chunk$3) and @ad<"20040430"	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 20:04
S42	0	live same sports WITH EVEN SAME ENCOD$3 and @ad<"20040430"	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 20:05
S43	0	live same sports WITH EVEN SAME BIT$2RATE and @ad<"20040430"	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 20:05
S44	2	scal$3 near2 video AND EVENT NEAR3 sports and (streamlet chunk$3) and @ad<"20040430"	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 20:06
S45	0	scal$3 near2 video SAME EVENT NEAR3 sports and @ad<"20040430"	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 20:07
S46	4	((H04N19/34 OR H04N19/40 OR H04N21/234327).CPC.) AND LIVE NEAR3 SPORTS and @ad<"20040430"	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/03/14 20:09
S47	1	("7934159").PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2019/03/18 12:27
S48	2	streamlets with live near2 stream with bitrate	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/08/20 11:16
S49	2	streamlets with live near2 stream	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/08/20 11:16
S50	15	streamlets with stream with bit$2rate	US-PGPUB; USPAT; USOCR;	OR	ON	2019/08/20 11:19

			FPRS; EPO			
S51	43	((H04N21/2662 OR H04N21/234327 OR H04N21/2393 OR H04L65/80 OR H04L67/2842 OR H04L65/4069 OR H04L65/607 OR H04L65/608).CPC.) and streamlets with bitrate	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/08/20 11:40
S52	43	((H04N21/2662 OR H04N21/234327 OR H04N21/2393 OR H04L65/80 OR H04L67/2842 OR H04L65/4069 OR H04L65/607 OR H04L65/608).CPC.) and streamlets with bitrate	US-PGPUB; USPAT; USOCR; FPRS; EPO	OR	ON	2019/08/20 11:41
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EAST Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S53	39	((H04N21/2662 OR H04N21/234327 OR H04N21/2393 OR H04L65/80 OR H04L67/2842 OR H04L65/4069 OR H04L65/607 OR H04L65/608).CPC.) and streamlets and live adj event	US-PGPUB; USPAT	OR	ON	2019/08/21 08:11
S54	42	((H04N21/2662 OR H04N21/234327 OR H04N21/2393 OR H04L65/80 OR H04L67/2842 OR H04L65/4069 OR H04L65/607 OR H04L65/608).CPC.) and streamlets with bitrates	US-PGPUB; USPAT	OR	ON	2019/08/21 08:12
S55	31	((H04N21/2662 OR H04N21/234327 OR H04N21/2393 OR H04L65/80 OR H04L67/2842 OR H04L65/4069 OR H04L65/607 OR H04L65/608).CPC.) and streamlets with bitrates and live adj event	US-PGPUB; USPAT	OR	ON	2019/08/21 08:12
S56	22	streamlet with live adj event AND LOW near quality AND medium adj quality AND high adj quality	US-PGPUB; USPAT	OR	ON	2019/08/21 08:13
S57	2	streamlet with live adj event AND different near3 bit$2rate	US-PGPUB; USPAT	OR	ON	2019/08/21 08:50
S58	2	streamlet with live adj event AND different near3 bit$2rate	US-PGPUB; USPAT	OR	ON	2019/08/21 11:39

8/ 22/ 2019 8:01:28 AM
C:\ Users\ cpatel\ Documents\ EAST\ Workspaces\ 16252188.wsp

Bibliographic Data

Application No: 16/252,188

Foreign Priority claimed: ○ Yes ◉ No

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

Verified and Acknowledged: /CHIRAG R PATEL/ Examiner's Signature | Initials

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

FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
01/18/2019	709	2454	066.0141X1C7
RULE			

APPLICANTS

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INVENTORS

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MARK B. HURST CEDAR HILLS, UT, UNITED STATES

R. DREW MAJOR OREM, UT, UNITED STATES

CONTINUING DATA

This application is a CON of 16004056 06/08/2018

16004056 is a CON of 15414025 01/24/2017 PAT 9998516

15414025 is a CON of 14719122 05/21/2015 PAT 9571551

14719122 is a CON of 14106051 12/13/2013 PAT 9071668

14106051 is a CON of 13617114 09/14/2012 PAT 8612624

13617114 is a CON of 12906940 10/18/2010 PAT 8402156

12906940 is a CON of 11673483 02/09/2007 PAT 7818444

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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02/08/2019

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7010 E. COCHISE ROAD
SCOTTSDALE, AZ 85253
UNITED STATES

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$7,320

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Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

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

(Not for submission under 37 CFR 1.99)

Application Number	16252188
Filing Date	2019-01-18
First Named Inventor	David F. Brueck
Art Unit	2454
Examiner Name	Chirag R. Patel
Attorney Docket Number	066.0141X1C7

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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
	1	5267334	A	1993-11-30	Normille et al.	
	2	5404446	A	1995-04-04	Bowater et al.	
	3	5841432	A	1998-11-24	Carmel et al.	

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Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20020156912	A1	2002-10-24	Hurst et al.	
	2	20030055995	A1	2003-03-20	Ala Honkola	

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
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	Examiner Name	Chirag R. Patel
	Attorney Docket Number	066.0141X1C7

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Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	1	ROY, S., et al., "Architecture of a Modular Streaming Media Server for Content Delivery Networks," 2002 IEEE. Published in the 2003 International Conference on Multimedia and Expo ICME 2003.	☒
	2	BOMMAIAH, E., et al., "Design and Implementation of a Caching System for Streaming Media over the Internet," 2000 IEEE. Published in RTAS '00 Proceedings of the Sixth IEEE Real Time Technology and Applications Symposium (RTAS 2000), page 111.	☒

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EXAMINER SIGNATURE

Examiner Signature	/CHIRAG R PATEL/	Date Considered	08/22/2019

*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	16252188
	Filing Date	2019-01-18
	First Named Inventor	David F. Brueck
	Art Unit	2454
	Examiner Name	Chirag R. Patel
	Attorney Docket Number	066.0141X1C7

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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).

☒ See attached certification statement.

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

None

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)	2019-06-27
Name/Print	Brett A. Carlson	Registration Number	39928

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

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Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/252,188	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	03/18/2019	08/22/2019							
	1	✓	=							
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	29	✓	=							
	30	✓	=							

fuboTV Media Inc.
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Page 646

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Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

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Examiner Name	Chirag R. Patel
Attorney Docket Number	066.0141X1C7

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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
	1	8521836	B2	2013-08-27	Kewalramani et al.	
	2	7558869	B2	2009-07-07	Leon et al.	
	3	7707303	B2	2010-04-27	Albers et al.	
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	5	8880721	B2	2014-11-04	Hurst et al.	
	6	9344496	B2	2016-05-17	Hurst et al.	
	7	8683066	B2	2014-03-25	Hurst et al.	
	8	8686066	B2	2014-04-01	Kwampian et al.	

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
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	First Named Inventor	David F. Brueck
	Art Unit	2454
	Examiner Name	Chirag R. Patel
	Attorney Docket Number	066.0141X1C7

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /C.R.P/

	9	6708213	B1	2004-03-16	Bommaiah et al.	
	10	6757796	B1	2004-06-29	Hofmann	
	11	9462074	B2	2016-10-04	Guo et al.	

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	1	20050033855	A1	2005-02-10	Moradi et al.	
	2	20030093790	A1	2003-05-15	Logan et al.	
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	Art Unit	2454
	Examiner Name	Chirag R. Patel
	Attorney Docket Number	066.0141X1C7

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /C.R.P/

	7	20060010003	A1	2006-01-12	Kruse	
	8	20060277564	A1	2006-12-07	Jarman	
	9	20150058496	A1	2015-02-26	Hurst et al.	
	10	20100262711	A1	2010-10-14	Bouazizi	
	11	20050251832	A1	2005-11-10	Chiueh	
	12	20040221088	A1	2004-11-04	Lisitsa et al.	
	13	20040179032	A1	2004-09-16	Huang	
	14	20020161908	A1	2002-10-31	Benitez et al.	
	15	20030021282	A1	2003-01-30	Hospodor	
	16	20080120330	A1	2008-05-22	Reed et al.	
	17	20080120342	A1	2008-05-22	Reed et al.	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /C.R.P/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	16252188
	Filing Date	2019-01-18
	First Named Inventor	David F. Brueck
	Art Unit	2454
	Examiner Name	Chirag R. Patel
	Attorney Docket Number	066.0141X1C7

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /C.R.P/

	18	20110307545	A1	2011-12-15	BOUAZIZI	
	19	20050262257	A1	2005-11-24	Major et al.	
	20	20030236904	A1	2003-12-25	Walpole et al.	

If you wish to add additional U.S. Published Application citation information please click the Add button. Add

FOREIGN PATENT DOCUMENTS Remove

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2]	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1							

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Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	1	Krasic et al., QUALITY-ADAPTIVE MEDIA STREAMING BY PRIORITY DROP, Oregon Graduate Institute, 2001.	☓
	2	Krasic et al., QoS SCALABILITY FOR STREAMED MEDIA DELIVERY, Oregon Graduate Institute School of Science & Engineering Technical Report CSE 99-011, September 1999.	☒
	3	Huang et al., ADAPTIVE LIVE VIDEO STREAMING BY PRIORITY DROP, Portland State University PDXScholar, July 21, 2003.	☒

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	4	Walpole et al, A PLAYER FOR ADAPCTIVE MPEG VIDEO STREAMING OVER THE INTERNET, Oregon Graduate Institute of Science and Technology, October 25, 2012.	☒
	5	ALBANESE, ANDREW ET AL. "Priority Encoding Transmission", TR-94-039, August 1994, 36 pgs, International Computer Science Institute, Berkeley, CA.	☒
	6	BIRNEY, BILL "Intelligent Streaming", May 2003, Microsoft.	☒
	7	GOYAL, VIVEK K. "Multiple Description Coding: Compression Meets the Network," September 2001, pgs. 74-93, IEEE Signal Processing Magazine.	☒
	8	ON2 TECHNOLOGIES, INC. "TrueMotion VP7 Video Codec" White Paper, Document Version 1.0, January 10, 2005.	☒
	9	PATHAN, AL-MUKADDIM ET AL. "A Taxonomy and Survey of Content Delivery Networks" Australia, February 2007, available at http://www.gridbus.org/reports/CDN-Taxonomy.pdf.	☒
	10	PURI, ROHIT ET AL. "Multiple Description Source Coding Using Forward Error Correction Codes," October 1999, 5 pgs., Department of Electrical Engineering and Computer Science, University of California, Berkeley, CA.	☒
	11	WICKER, STEPHEN B. "Error Control Systems for Digital Communication and Storage," Prentice-Hall, Inc., New Jersey, USA, 1995, parts 1-6.	☒
	12	LIU, JIANGCHUAN ET AL. "Opportunities and Challenged of Peer-to-Peer Internet Video Broadcast," School of Computing Science, Simon Fraser University, British Columbia, Canada.	☒
	13	CLEMENT, B. "Move Networks closes $11.3 Million on First Round VC Funding," Page One PR, Move Networks, Inc. Press Releases, February 7, 2007, http://www.move.tv/press/press20070201.html.	☒
	14	MOVE NETWORKS, INC. "The Next Generation Video Publishing System," April 11, 2007; http://www.movenetworks.com/wp-content/uploads/move-networks-publishing-system.pdf.	☒

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	Attorney Docket Number	066.0141X1C7

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	15	YOSHIMURA, TAKESHI ET AL. "Mobile Streaming Media CDN Enabled by Dynamic SMIL", NTT DoCoMo, Multimedia Laboratories and Hewlett-Packard Laboratories,dated May 7-11, 2002, ACM 1-58113-449-5/02/0005; http://www2002.org/CDROM/refereed/515/.	☒
	16	Nguyen, T. et al., Multiple Sender Distributed Video Streaming, IEEE TRANSACTINOS ON MULTIMEDIA, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 6, no. 2, April 1, 2004, pages 315-326, XP011109142, ISSN: 1520-9210, DOI: 10.1109/TMM.2003.822790.	☒

If you wish to add additional non-patent literature document citation information please click the Add button Add

EXAMINER SIGNATURE

Examiner Signature	/CHIRAG R PATEL/	Date Considered	08/21/2019

*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.

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	Art Unit	2454
	Examiner Name	Chirag R. Patel
	Attorney Docket Number	066.0141X1C7

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /C.R.P/

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).

☒ 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)	2019-06-27
Name/Print	Brett A. Carlson	Registration Number	39928

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /C.R.P/

Privacy Act Statement

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. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these record s.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

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UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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Alexandria, Virginia 22313-1450
www.uspto.gov

NOTICE OF ALLOWANCE AND FEE(S) DUE

70560 7590 09/13/2019

LKGLOBAL (Dish Technologies L.L.C.)
7010 E. COCHISE ROAD
SCOTTSDALE, AZ 85253

EXAMINER	
PATEL, CHIRAG R	
ART UNIT	PAPER NUMBER
2454	

DATE MAILED: 09/13/2019

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/252,188	01/18/2019	DAVID F. BRUECK	066.0141X1C7	3722

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	$1000	$0.00	$0.00	$1000	12/13/2019

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE 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.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

If the ENTITY STATUS is the same as shown above, pay the TOTAL FEE(S) DUE shown above.

If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 titled "Change in Entity Status (from status indicated above)".

For purposes of this notice, small entity fees are 1/2 the amount of undiscounted fees, and micro entity fees are 1/2 the amount of small entity fees.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Maintenance fees are due in utility patents issuing on applications filed on or after Dec. 12, 1980. It is patentee's responsibility to ensure timely payment of maintenance fees when due. More information is available at www.uspto.gov/PatentMaintenanceFees.

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Page 655

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), by mail or fax, or via EFS-Web.

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 including the Patent, advance orders and notification of maintenance fees 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.

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

70560 7590 09/13/2019

LKGLOBAL (Dish Technologies L.L.C.)
7010 E. COCHISE ROAD
SCOTTSDALE, AZ 85253

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 EFS-Web 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.
16/252,188	01/18/2019	DAVID F. BRUECK	066.0141X1C7	3722

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	$1000	$0.00	$0.00	$1000	12/13/2019

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/SB/122) attached.

❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-09 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 _____
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 (B) RESIDENCE: (CITY and STATE OR COUNTRY)

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) ❑ Advance Order - # of Copies _____

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

❑ Electronic Payment via EFS-Web ❑ 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. _____

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

❑ Applicant certifying micro entity status. See 37 CFR 1.29

❑ Applicant asserting small entity status. See 37 CFR 1.27

❑ Applicant changing to regular undiscounted fee status.

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.
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.
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 _____ Date _____

Typed or printed name _____ Registration No. _____

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Exhibit 1002
Page 656

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United States Patent and Trademark Office
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www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/252,188	01/18/2019	DAVID F. BRUECK	066.0141X1C7	3722

70560 7590 09/13/2019

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7010 E. COCHISE ROAD
SCOTTSDALE, AZ 85253

EXAMINER	
PATEL, CHIRAG R	
ART UNIT	PAPER NUMBER
2454	

DATE MAILED: 09/13/2019

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

The Office has discontinued providing a Patent Term Adjustment (PTA) calculation with the Notice of Allowance.

Section 1(h)(2) of the AIA Technical Corrections Act amended 35 U.S.C. 154(b)(3)(B)(i) to eliminate the requirement that the Office provide a patent term adjustment determination with the notice of allowance. See Revisions to Patent Term Adjustment, 78 Fed. Reg. 19416, 19417 (Apr. 1, 2013). Therefore, the Office is no longer providing an initial patent term adjustment determination with the notice of allowance. The Office will continue to provide a patent term adjustment determination with the Issue Notification Letter that is mailed to applicant approximately three weeks prior to the issue date of the patent, and will include the patent term adjustment on the patent. Any request for reconsideration of the patent term adjustment determination (or reinstatement of patent term adjustment) should follow the process outlined in 37 CFR 1.705.

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

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Exhibit 1002
Page 657

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 30 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. 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.

Privacy Act Statement

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The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
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7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Notice of Allowability	Application No. 16/252,188	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 response filed on June 20, 2019.
   ☐ 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 1-30 . 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 6/27/19, 6/27/19, 6/27/19.
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

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Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (01-10)
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Art Unit	2454
Examiner Name	Patel, Chirag R.
Attorney Docket Number	066.0141X1C7

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ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /C.R.P/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	16252188
	Filing Date	2019-01-18
	First Named Inventor	David F. Brueck
	Art Unit	2454
	Examiner Name	Patel, Chirag R.
	Attorney Docket Number	066.0141X1C7

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /C.R.P/

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Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	16252188
	Filing Date	2019-01-18
	First Named Inventor	David F. Brueck
	Art Unit	2454
	Examiner Name	Patel, Chirag R.
	Attorney Docket Number	066.0141X1C7

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99**)	
Application Number	16252188
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Examiner Name	Patel, Chirag R.
Attorney Docket Number	066.0141X1C7

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Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	16252188
	Filing Date	2019-01-18
	First Named Inventor	David F. Brueck
	Art Unit	2454
	Examiner Name	Patel, Chirag R.
	Attorney Docket Number	066.0141X1C7

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /C.R.P/

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EXAMINER SIGNATURE

Examiner Signature	/CHIRAG R PATEL/	Date Considered	08/22/2019

*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.

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**	Application Number	16252188
	Filing Date	2019-01-18
	First Named Inventor	David F. Brueck
	Art Unit	2454
	Examiner Name	Patel, Chirag R.
	Attorney Docket Number	066.0141X1C7

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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).

☒ 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)	2019-06-27
Name/Print	Brett A. Carlson	Registration Number	39928

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/252,188	BRUECK et al.
	Examiner	Art Unit
	CHIRAG R PATEL	2454

CPC - Searched*		
Symbol	Date	Examiner
H04N19/34, H04N19/40, H04N21/23427	03/14/2019	C.P.
H04N21/2662, H04N21/234327, H04N21/2393, H04L65/80, H04L67/2842, H04L65/4069, H04L65/607. H04L65/608	08/21/2019	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		
Search Notes	Date	Examiner
EAST	03/14/2019	C.P.
Inventor / Double patent search	03/14/2019	C.P.
EAST	08/22/2019	C.P.
IP.COM	08/22/2019	C.P.

Interference Search			
US Class/CPC Symbol	US Subclass/CPC Group	Date	Examiner
H04N	H04N21/2662, H04N21/234327, H04N21/2393,	08/22/2019	C.P.
H04L	H04L65/80, H04L67/2842, H04L65/4069, H04L65/607. H04L65/608	08/22/2019	C.P.

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Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/252,188	BRUECK et al.
	Examiner	Art Unit
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CPC						
Symbol					**Type**	**Version**
H04L	/	65	/	607	F	2013-01-01
H04L	/	47	/	801	I	2013-01-01
H04L	/	47	/	12	I	2013-01-01
H04L	/	65	/	4069	I	2013-01-01
G06F	/	16	/	71	I	2019-01-01
G06F	/	16	/	183	I	2019-01-01
H04L	/	29	/	06027	I	2013-01-01
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	/	608	I	2013-01-01
H04L	/	67	/	02	I	2013-01-01
H04L	/	65	/	1069	I	2013-01-01
H04L	/	67	/	2842	I	2013-01-01
H04L	/	67	/	32	I	2013-01-01
H04N	/	21	/	2662	I	2013-01-01

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

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	30	
/CHIRAG R PATEL/ Primary Examiner, Art Unit 2454	22 August 2019	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	1

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Page 684

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
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INTERNATIONAL CLASSIFICATION					
CLAIMED					
H04L	/	29	/	06	

NON-CLAIMED					
	/		/		

US ORIGINAL CLASSIFICATION	
CLASS	**SUBCLASS**

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

NONE (Assistant Examiner) (Date)	**Total Claims Allowed:** 30	
/CHIRAG R PATEL/ Primary Examiner, Art Unit 2454 (Primary Examiner) 22 August 2019 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 1

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/252,188	BRUECK et al.
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☑ 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		19		28								
	2		11		20		29								
	3		12		21		30								
	4		13		22										
	5		14		23										
	6		15		24										
	7		16		25										
	8		17		26										
	9		18		27										

NONE (Assistant Examiner)	(Date)	**Total Claims Allowed:** 30	
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Page 686

Complete Main Concept Text
==========
select streamlets live video bitrates

(No Concept Modifiers)
==========

(No Filters)
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Options
=======
De-dup: None
Cut-off: None
Sort: Relevance

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Other Literature: IBM Redbooks
Other Literature: PubMed Central

Bibliographic Data

Application No: 16/252,188

Foreign Priority claimed: ○ Yes ◉ No

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

Verified and Acknowledged: /CHIRAG R PATEL/ Examiner's Signature | Initials

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

FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
01/18/2019	709	2454	066.0141X1C7
RULE			

APPLICANTS

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CONTINUING DATA

This application is a CON of 16004056 06/08/2018

16004056 is a CON of 15414025 01/24/2017 PAT 9998516

15414025 is a CON of 14719122 05/21/2015 PAT 9571551

14719122 is a CON of 14106051 12/13/2013 PAT 9071668

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13617114 is a CON of 12906940 10/18/2010 PAT 8402156

12906940 is a CON of 11673483 02/09/2007 PAT 7818444

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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$7,320

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/252,188	BRUECK et al.
	Examiner	Art Unit
	CHIRAG R PATEL	2454

CPC						
Symbol					Type	Version
H04L	/	65	/	607	F	2013-01-01
H04L	/	47	/	801	I	2013-01-01
H04L	/	47	/	12	I	2013-01-01
H04L	/	65	/	4069	I	2013-01-01
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Symbol					Type	Set	Ranking	Version
	/		/					

NONE (Assistant Examiner)	(Date)	Total Claims Allowed: 30	
/CHIRAG R PATEL/ Primary Examiner, Art Unit 2454 (Primary Examiner)	01 October 2019 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 1

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fuboTV Media Inc.
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Page 694

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/252,188	BRUECK et al.
	Examiner	**Art Unit**
	CHIRAG R PATEL	2454

INTERNATIONAL CLASSIFICATION					
CLAIMED					
H04L	/	29	/	06	

NON-CLAIMED					
	/		/		

US ORIGINAL CLASSIFICATION	
CLASS	**SUBCLASS**

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

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	30	
/CHIRAG R PATEL/ Primary Examiner, Art Unit 2454	01 October 2019	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	1

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	16/252,188	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		19		28								
	2		11		20		29								
	3		12		21		30								
	4		13		22										
	5		14		23										
	6		15		24										
	7		16		25										
	8		17		26										
	9		18		27										

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	30	
/CHIRAG R PATEL/ Primary Examiner, Art Unit 2454	01 October 2019	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	1

U.S. Patent and Trademark Office

Part of Paper No.: 20191001

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Exhibit 1002
Page 696

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/252,188	01/18/2019	DAVID F. BRUECK	066.0141X1C7	3722

54583 7590 10/04/2019

DISH Technologies L.L.C.
9601 S. Meridian Blvd
ENGLEWOOD, CO 80112

EXAMINER	
PATEL, CHIRAG R	

ART UNIT	PAPER NUMBER
2454	

MAIL DATE	DELIVERY MODE
10/04/2019	PAPER

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.

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Corrected ***Notice of Allowability***	**Application No.** 16/252,188	**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 September 25, 2019.
   ☐ 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 1-30 . 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)).

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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 6/27/19.
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

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Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

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

(Not for submission under 37 CFR 1.99)

Application Number	16252188
Filing Date	2019-01-18
First Named Inventor	David F. Brueck
Art Unit	2454
Examiner Name	Patel, Chirag R.
Attorney Docket Number	066.0141X1C7

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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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Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
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	First Named Inventor	David F. Brueck
	Art Unit	2454
	Examiner Name	Patel, Chirag R.
	Attorney Docket Number	066.0141X1C7

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /C.R.P/

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	16252188
	Filing Date	2019-01-18
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ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /C.R.P/

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ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /C.R.P/

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Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
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	12	1202487	EP	A2	2002-05-02	Toshiba KK		
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Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	1	FUJISAWA, HIROSHI ET AL. "Implementaton of Efficient Access Mechanism for Multiple Mirror-Servers" IPSJ SIG Technical Report, vol. 2004, no. 9 (2004-DPS-116), January 30, 2004, Information Processing Society of Japan, pp. 37-42.	☒
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fuboTV Media Inc.
Exhibit 1002
Page 717

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	Examiner Name	Patel, Chirag R.
	Attorney Docket Number	066.0141X1C7

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EXAMINER SIGNATURE

Examiner Signature	/CHIRAG R PATEL/	Date Considered	10/01/2019

*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.

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	Attorney Docket Number	066.0141X1C7

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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).

☒ 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)	2019-06-27
Name/Print	Brett A. Carlson	Registration Number	39928

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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Change(s) applied to document, /J.E.B./ 9/20/2019	48	20080184688	A1	08/2008 ~~2008-08-17~~	Daly, et al. ~~Ganguly et al.~~	
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Change(s) applied to document, /J.E.B./ 9/20/2019

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	65	6968387		2005-11-22	Lanphear	
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APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/252,188	11/05/2019	10469554	066.0141X1C7	3722

54583 7590 10/16/2019

DISH Technologies L.L.C.
9601 S. Meridian Blvd
ENGLEWOOD, CO 80112

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

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 Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site http://pair.uspto.gov for additional applicants):

DAVID F. BRUECK, SARATOGA SPRINGS, UT;
DISH Technologies L.L.C., Englewood, CO
MARK B. HURST, CEDAR HILLS, UT;
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DOCKET NO.	DATE FILED	U.S. DISTRICT COURT
	4/13/2021	for the District of Delaware

PLAINTIFF	DEFENDANT
DISH Technologies L.L.C. and Sling TV L.L.C.	lululemon athletica inc. and Curiouser Products Inc. (d/b/a MIRROR)

	PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1	US 9,407,564 B2	8/2/2016	DISH Technologies L.L.C.
2	US 10,469,554 B2	11/5/2019	DISH Technologies L.L.C.
3	US 10,469,555 B2	11/5/2019	DISH Technologies L.L.C.
4	US 10,757,156 B2	8/25/2020	DISH Technologies L.L.C.
5	US 10,951,680 B2	3/16/2021	DISH Technologies L.L.C.

In the above—entitled case, the following patent(s)/ trademark(s) have been included:

DATE INCLUDED	INCLUDED BY ☐ Amendment ☐ Answer ☐ Cross Bill ☐ Other Pleading	
PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1		
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3		
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	4/13/2021	for the District of Delaware

PLAINTIFF	DEFENDANT
DISH Technologies L.L.C. and Sling TV L.L.C.	ICON Health & Fitness, Inc.

	PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1	US 9,407,564 B2	8/2/2016	DISH Technologies L.L.C.
2	US 10,469,554 B2	11/5/2019	DISH Technologies L.L.C.
3	US 10,469,555 B2	11/5/2019	DISH Technologies L.L.C.
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DOCKET NO.	DATE FILED	U.S. DISTRICT COURT
2:21-cv-00132	4/13/2021	Eastern District of Texas

PLAINTIFF	DEFENDANT
DISH TECHNOLOGIES L.L.C. and SLING TV L.L.C.	PELOTON INTERACTIVE, INC.

	PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1	9,407,564	8/2/2016	DISH Technologies L.L.C.
2	10,469,554	11/5/2019	DISH Technologies L.L.C.
3	10,469,555	11/5/2019	DISH Technologies L.L.C.
4	10,757,156	8/25/2020	DISH Technologies L.L.C.
5	10,951,680	3/16/2021	DISH Technologies L.L.C.

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Copy 2—Upon filing document adding patent(s), mail this copy to Director **Copy 4—Case file copy**