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(54) **USE OF OBJECTIVE QUALITY MEASURES OF STREAMED CONTENT TO REDUCE STREAMING BANDWIDTH**

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CPC .. H04N 19/102; H04N 19/154; H04N 19/164; H04N 19/177; H04N 19/46
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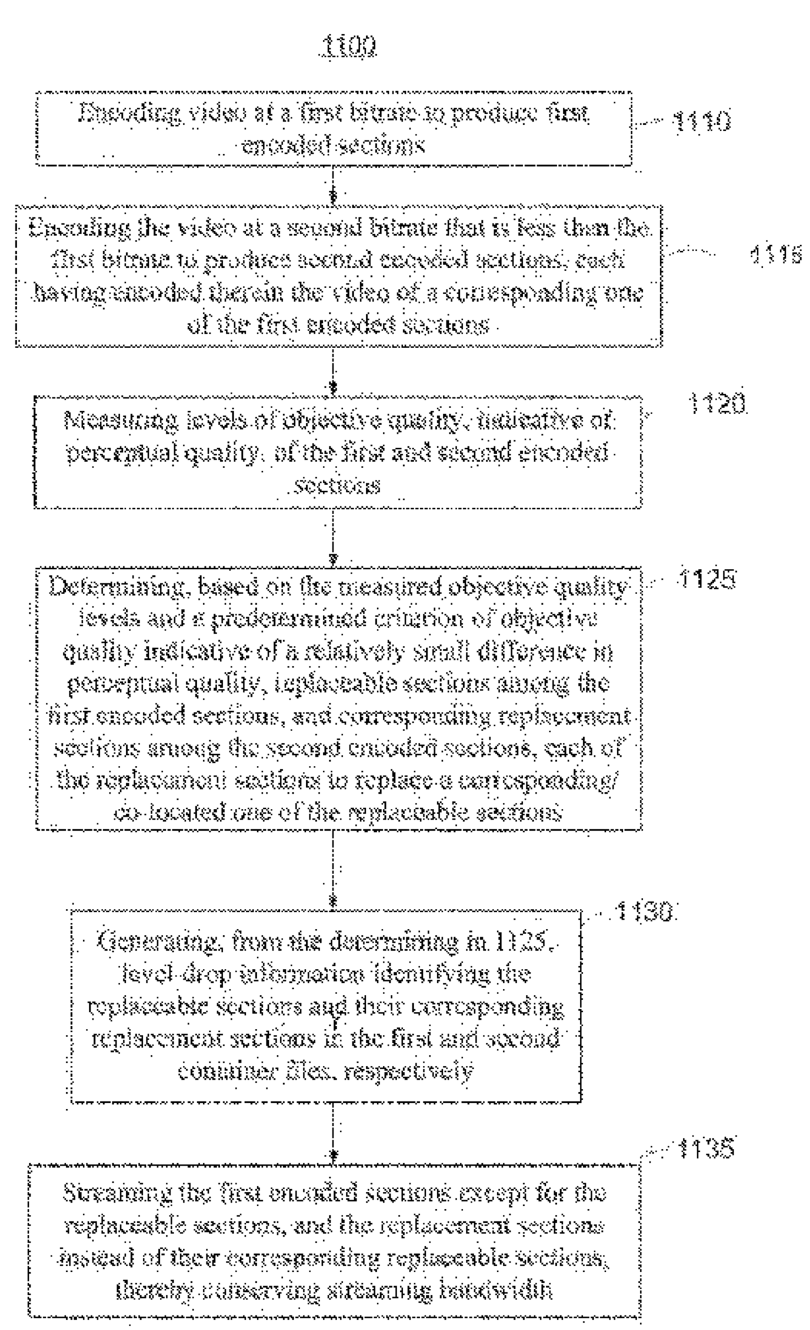
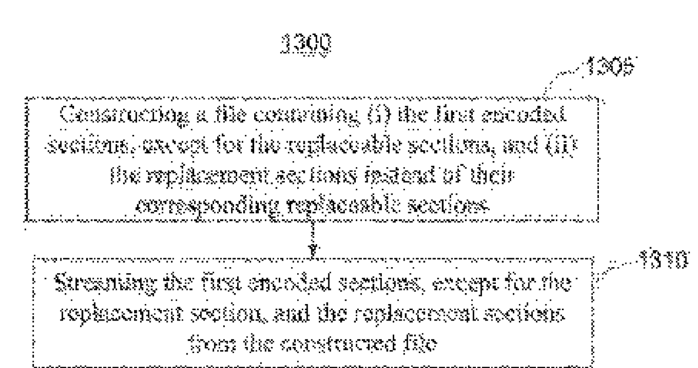
(57) **ABSTRACT**

A method includes encoding video at a first bitrate to produce first encoded sections, and at a second bitrate that is less than the first bitrate to produce second encoded sections. The method further includes measuring levels of objective quality, indicative of perceptual quality, of the first and second encoded sections. The method includes determining, based on the measured objective quality levels, replaceable sections among the first encoded sections, and replacement sections among the second encoded sections, each of the replacement sections to replace a corresponding one of the replaceable sections. the method includes streaming the first encoded sections except for the replaceable sections, and the replacement sections instead of their corresponding replaceable sections.

27 Claims, 13 Drawing Sheets





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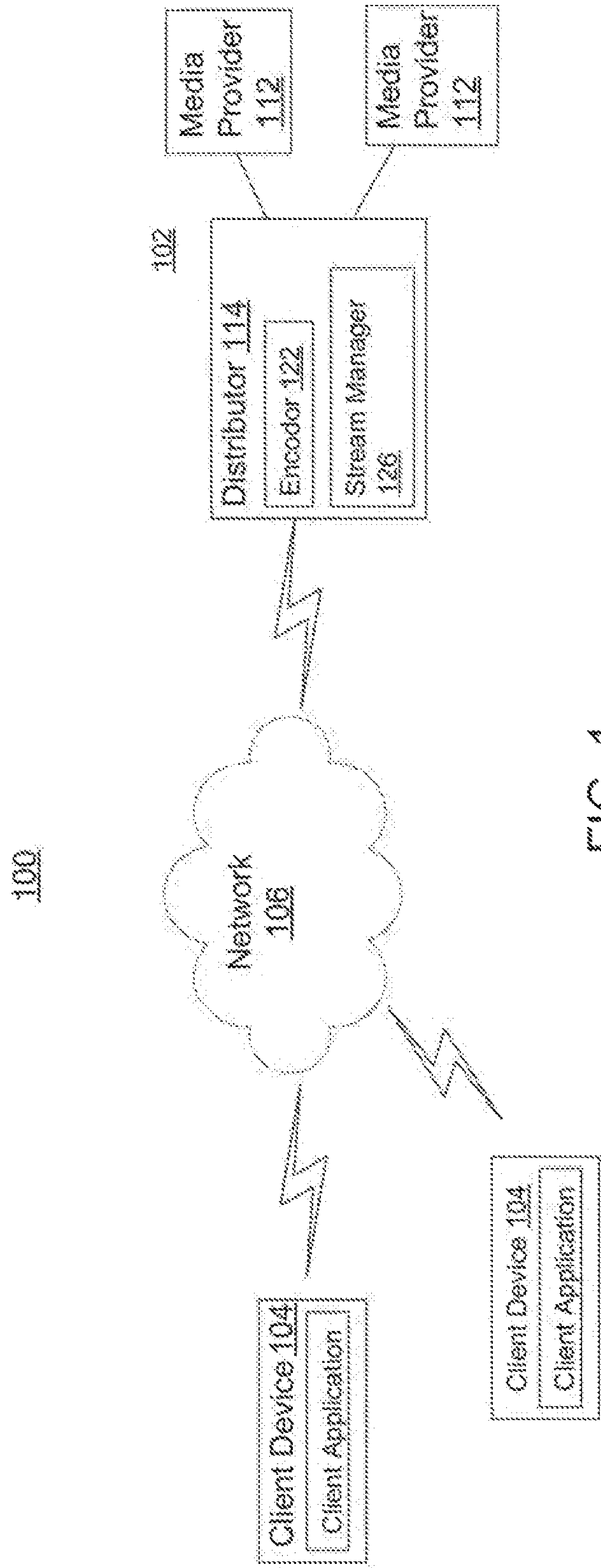

Media Provider 112
Media Provider 112
102
Distributor 114
Encoder 122
Stream Manager 126
100
Network 106
Client Device 104
Client Application
Client Device 104
Client Application

FIG. 1

FIG. 2

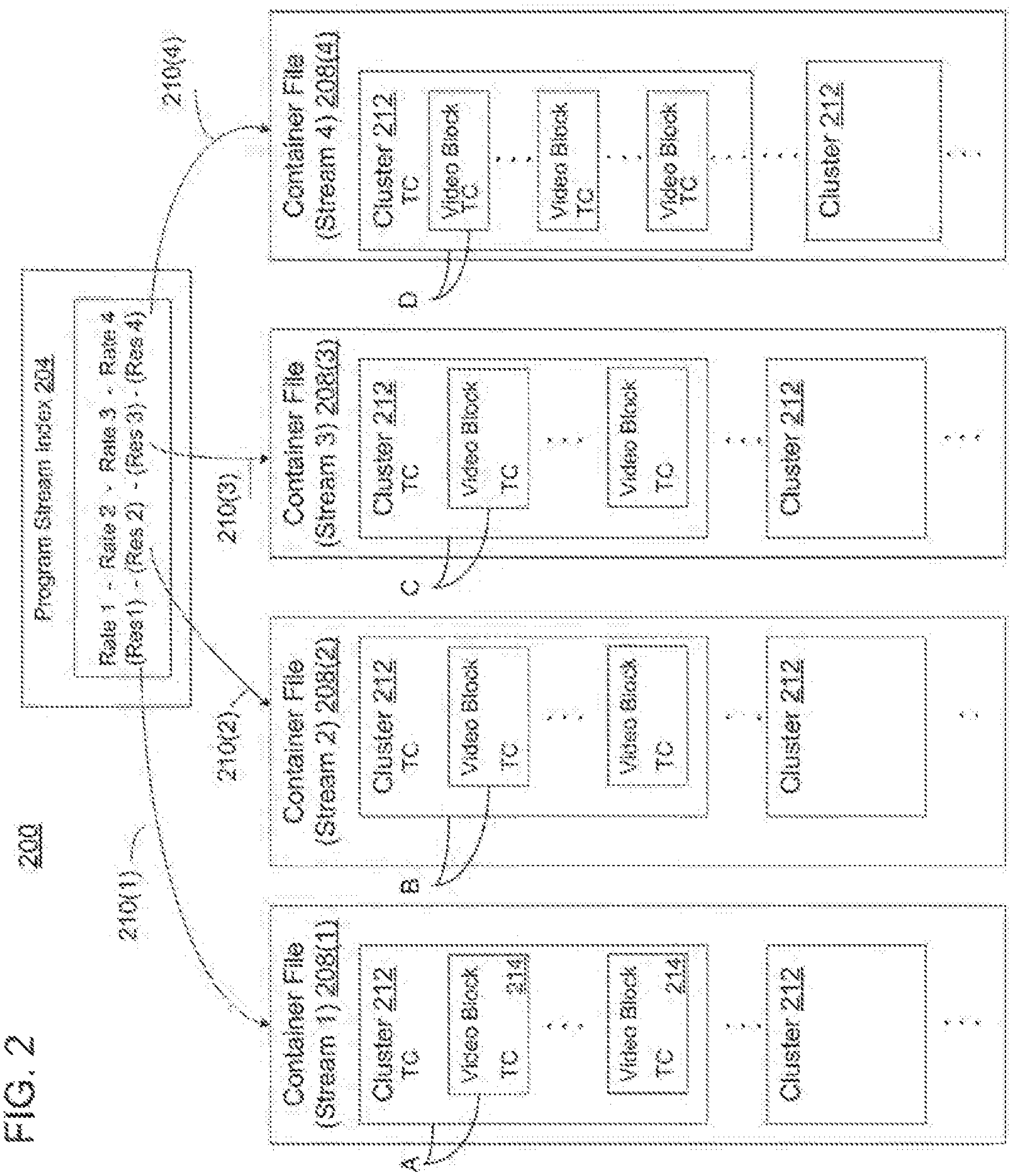

200
Program Stream Index 204
Rate 1 - Rate 2 - Rate 3 - Rate 4
(Res 1) - (Res 2) - (Res 3) - (Res 4)
210(1)
210(2)
210(3)
210(4)
Container File (Stream 1) 208(1)
Container File (Stream 2) 208(2)
Container File (Stream 3) 208(3)
Container File (Stream 4) 208(4)
Cluster 212 TC
Video Block TC 214
Video Block TC
Cluster 212
A
B
C
D

FIG 3

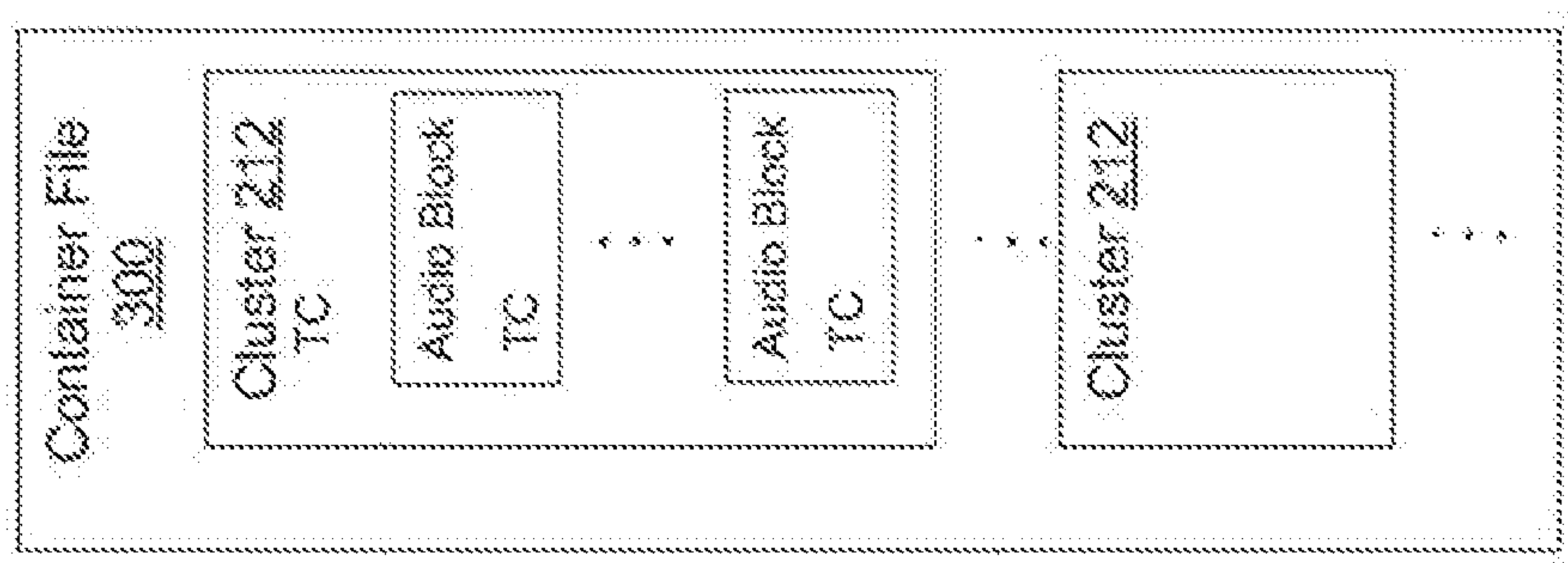


FIG. 4

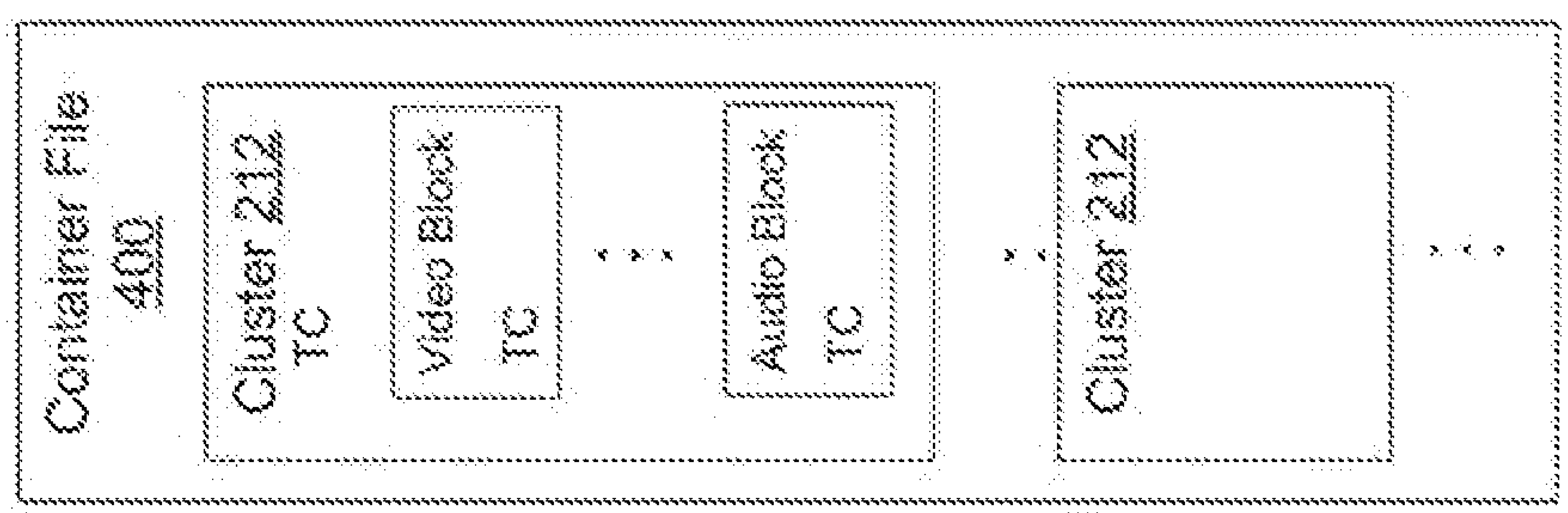
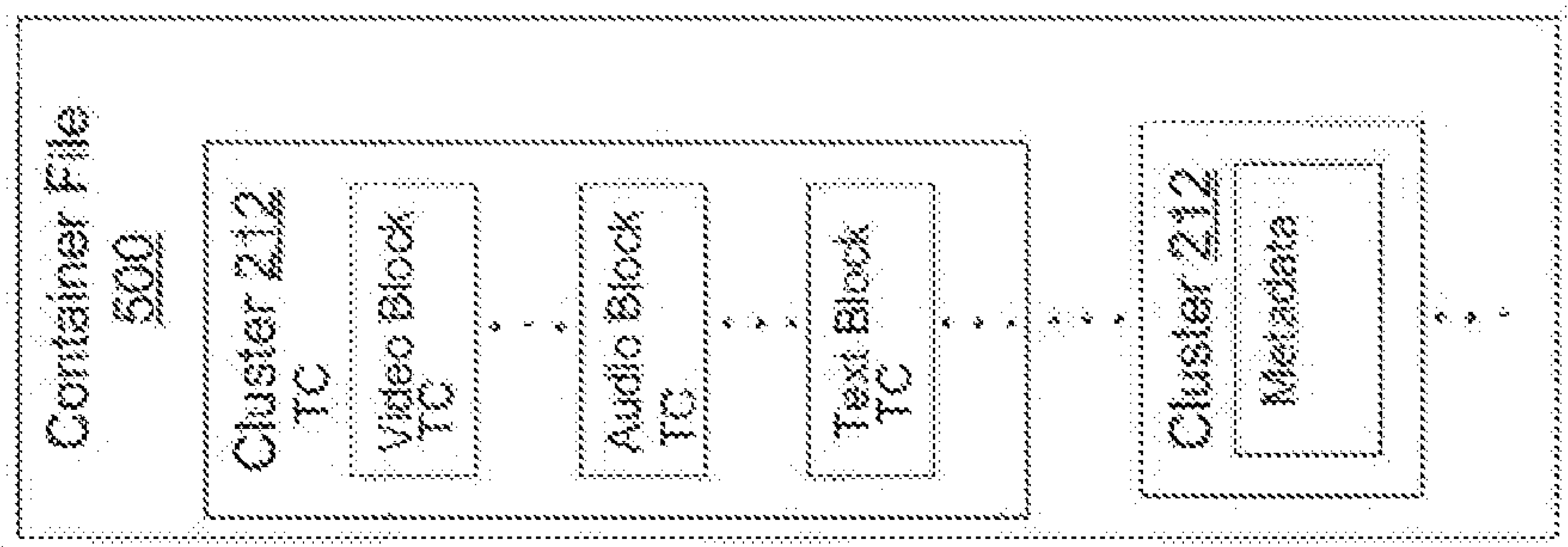


FIG. 5



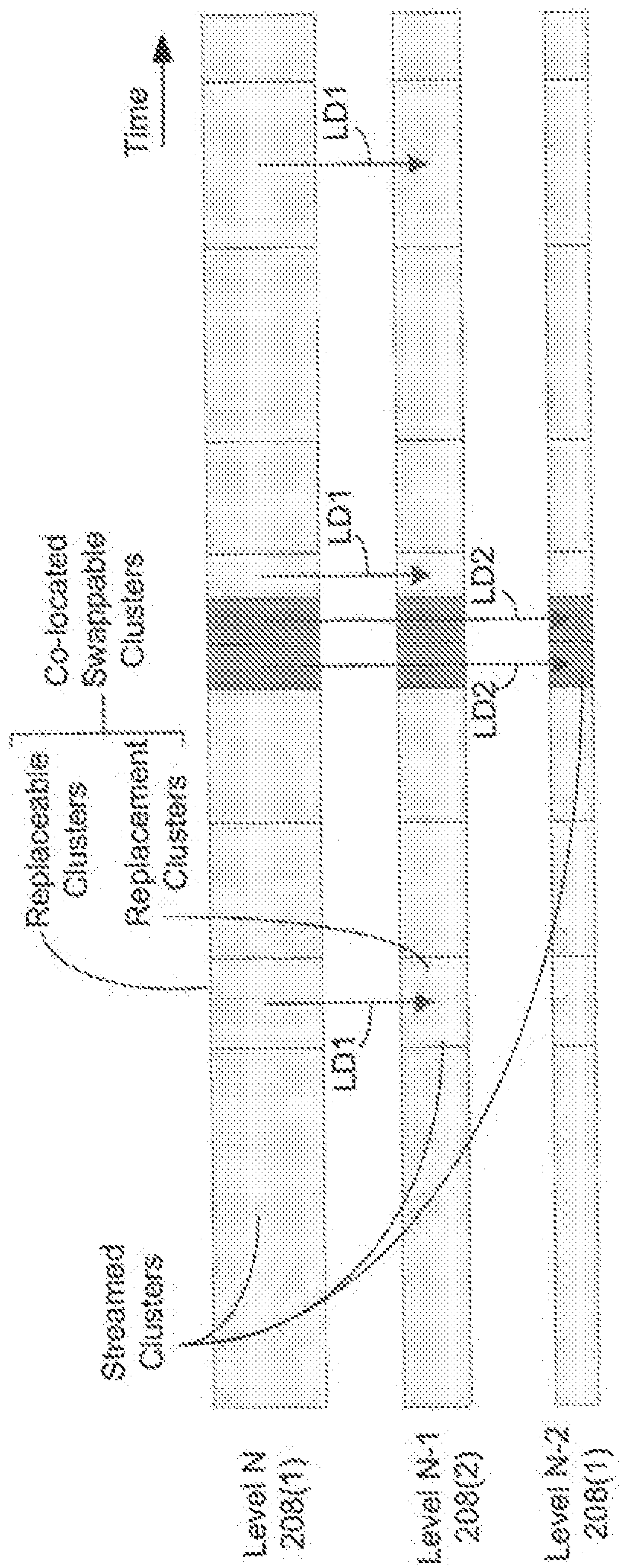

Time
LD1
LD1
LD2
LD2
Co-located Swappable Clusters
Replaceable Clusters
Replacement Clusters
LD1
Streamed Clusters
Level N 208(1)
Level N-1 208(2)
Level N-2 208(1)

FIG. 6

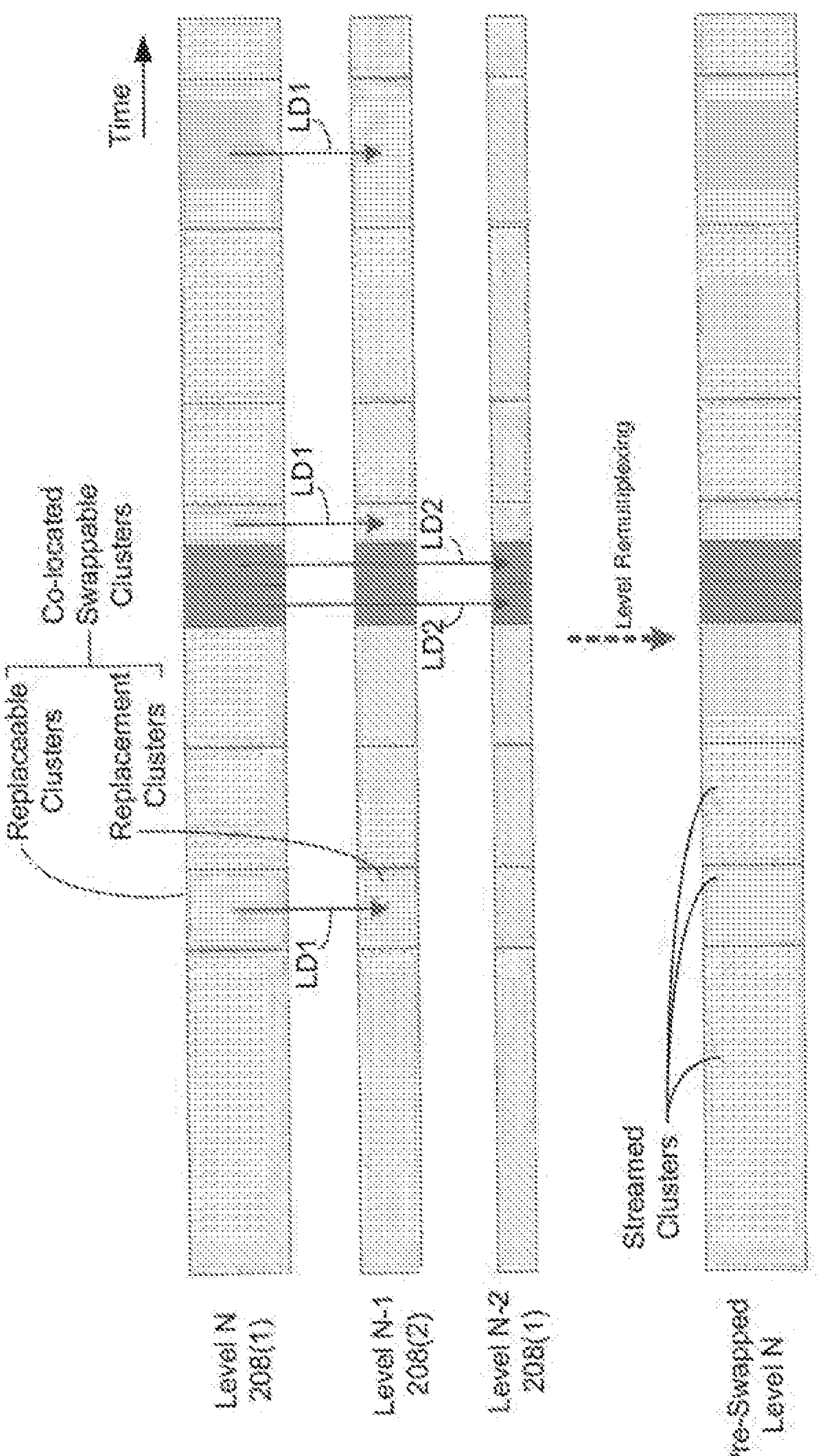

Time
LD1
Co-located Swappable Clusters
LD1
LD2
LD2
Replaceable Clusters
Replacement Clusters
LD1
Level Remultiplexing
Streamed Clusters
Level N 208(1)
Level N-1 208(2)
Level N-2 208(1)
re-Swapped Level N

FIG. 7

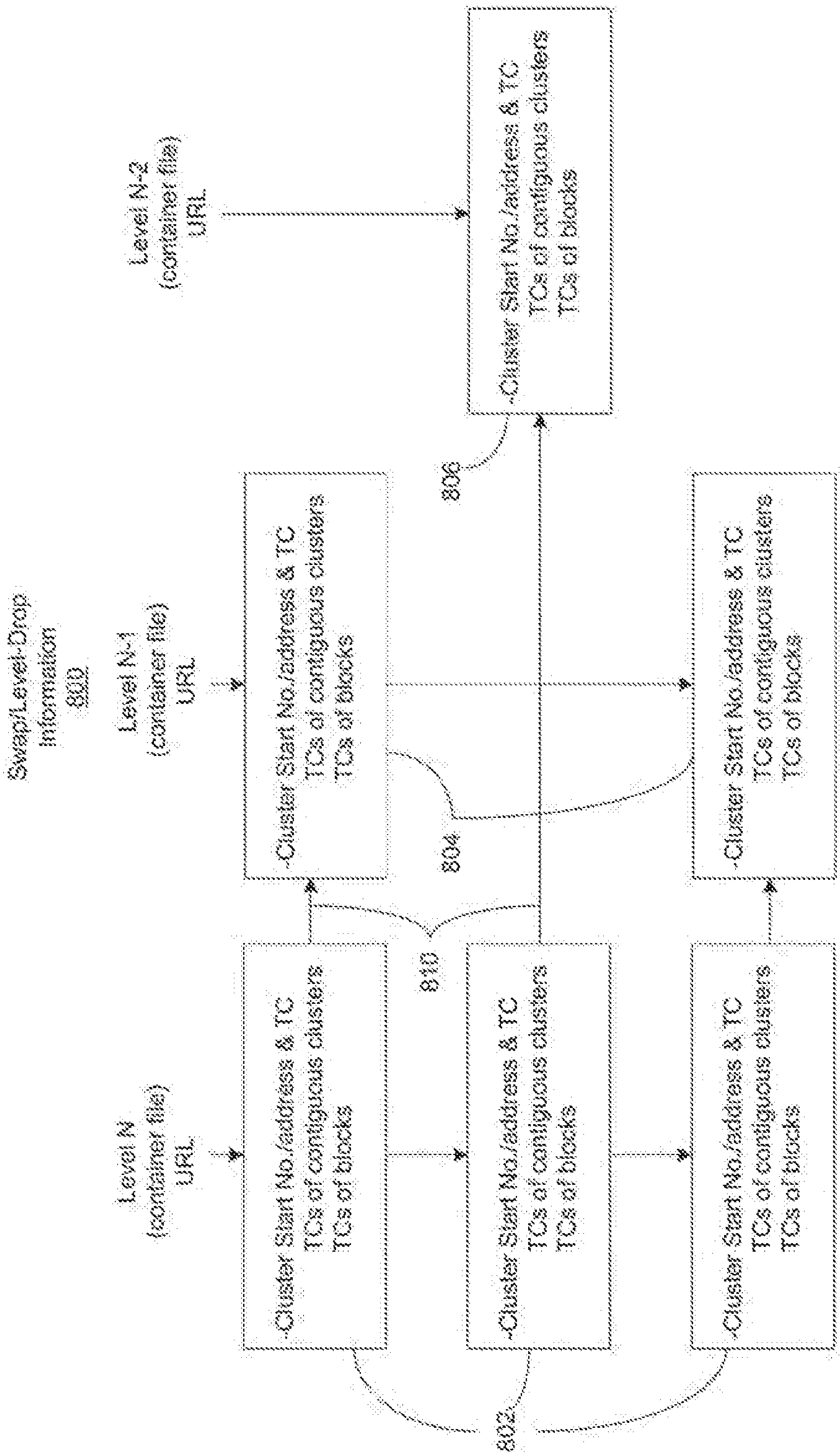

Swap/Level-Drop
Information
800
Level N
(container file)
URL
Level N-1
(container file)
URL
Level N-2
(container file)
URL
-Cluster Start No./address & TC
TCs of contiguous clusters
TCs of blocks
802
804
806
810

FIG. 8

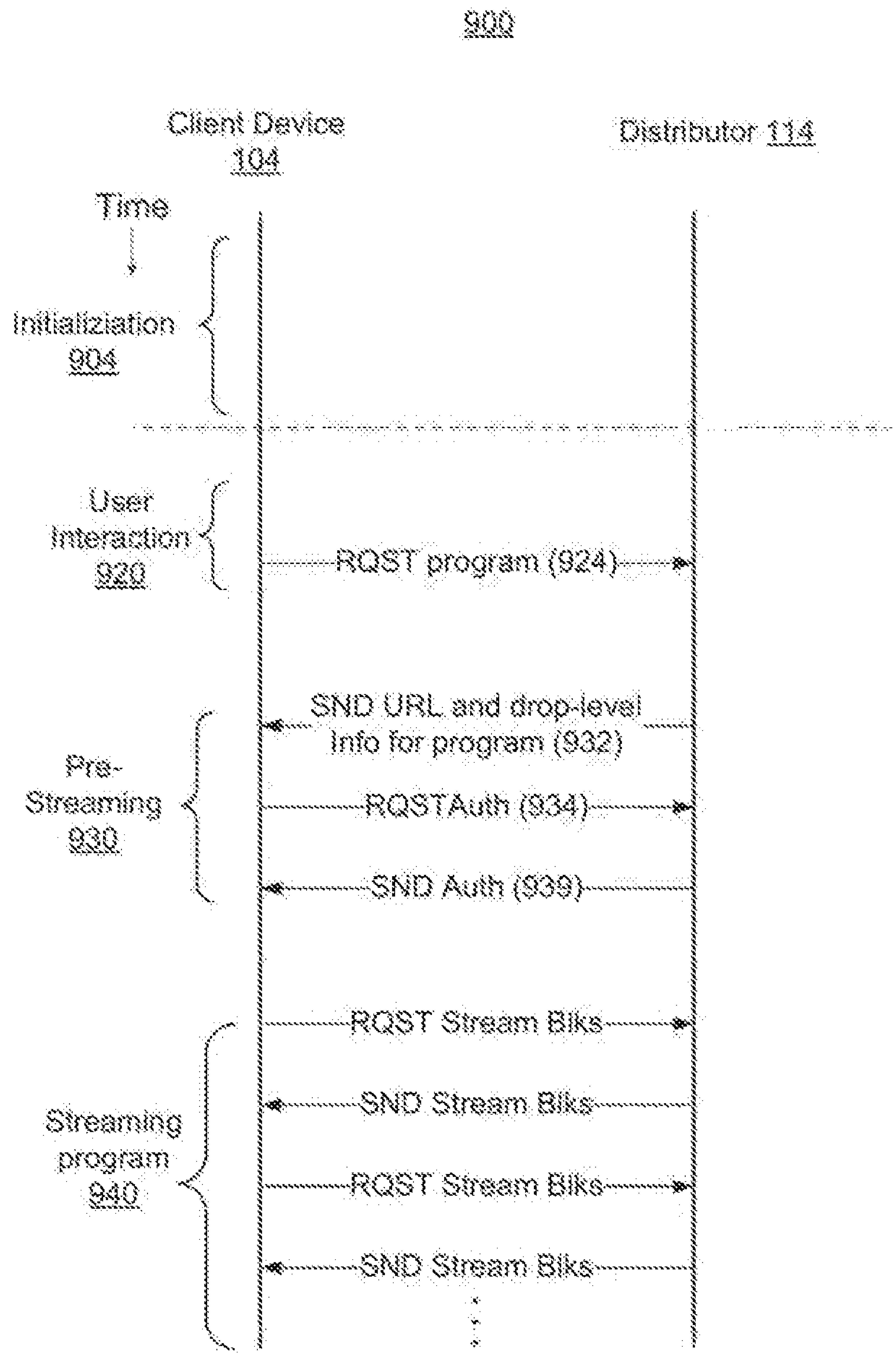

900
Client Device 104
Distributor 114
Time
Initializiation 904
User Interaction 920
RQST program (924)
SND URL and drop-level Info for program (932)
Pre-Streaming 930
RQSTAuth (934)
SND Auth (939)
RQST Stream Blks
SND Stream Blks
Streaming program 940
RQST Stream Blks
SND Stream Blks

FIG. 9

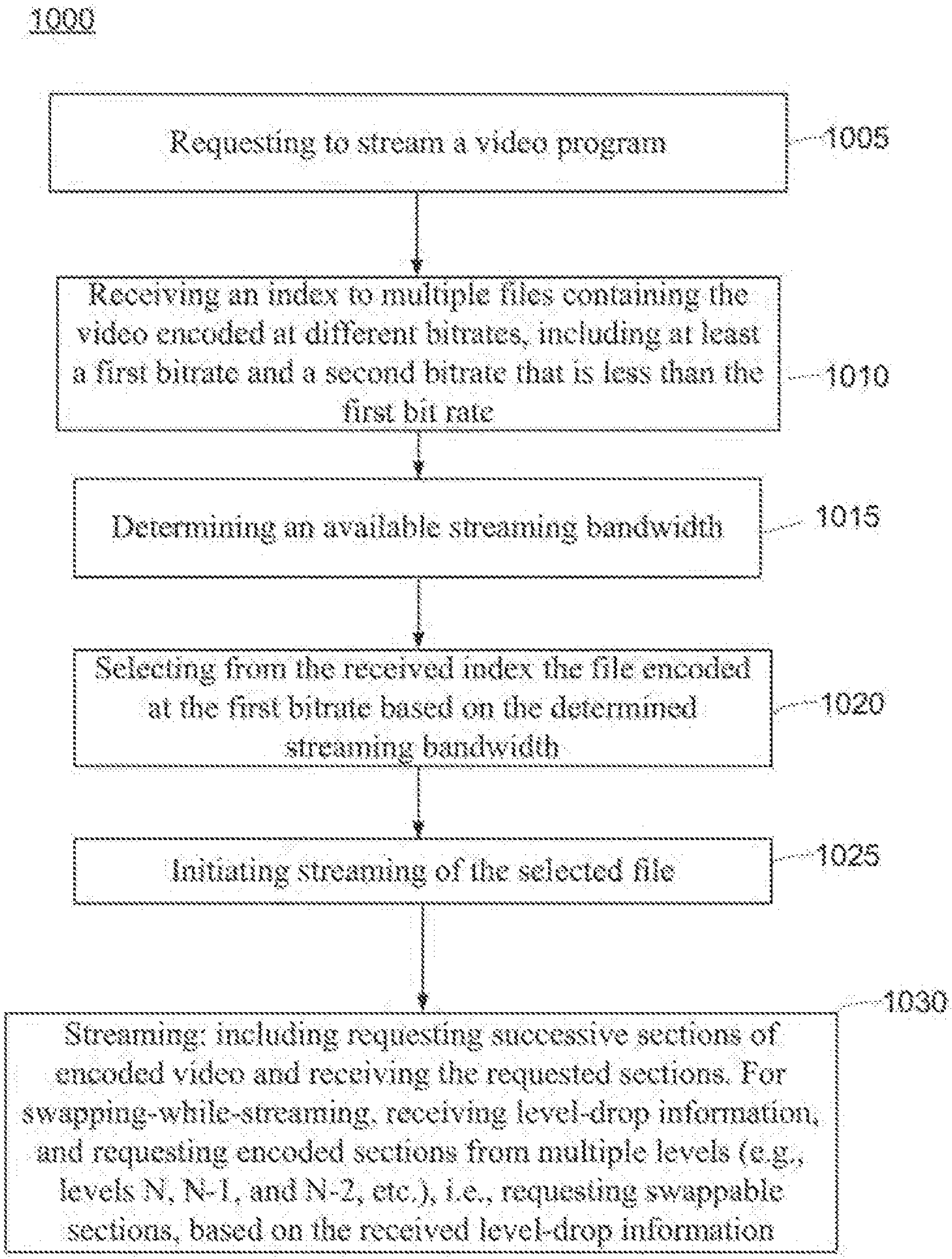

1000
Requesting to stream a video program
1005
Receiving an index to multiple files containing the video encoded at different bitrates, including at least a first bitrate and a second bitrate that is less than the first bit rate
1010
Determining an available streaming bandwidth
1015
Selecting from the received index the file encoded at the first bitrate based on the determined streaming bandwidth
1020
Initiating streaming of the selected file
1025
Streaming: including requesting successive sections of encoded video and receiving the requested sections. For swapping-while-streaming, receiving level-drop information, and requesting encoded sections from multiple levels (e.g., levels N, N-1, and N-2, etc.), i.e., requesting swappable sections, based on the received level-drop information
1030

FIG. 10

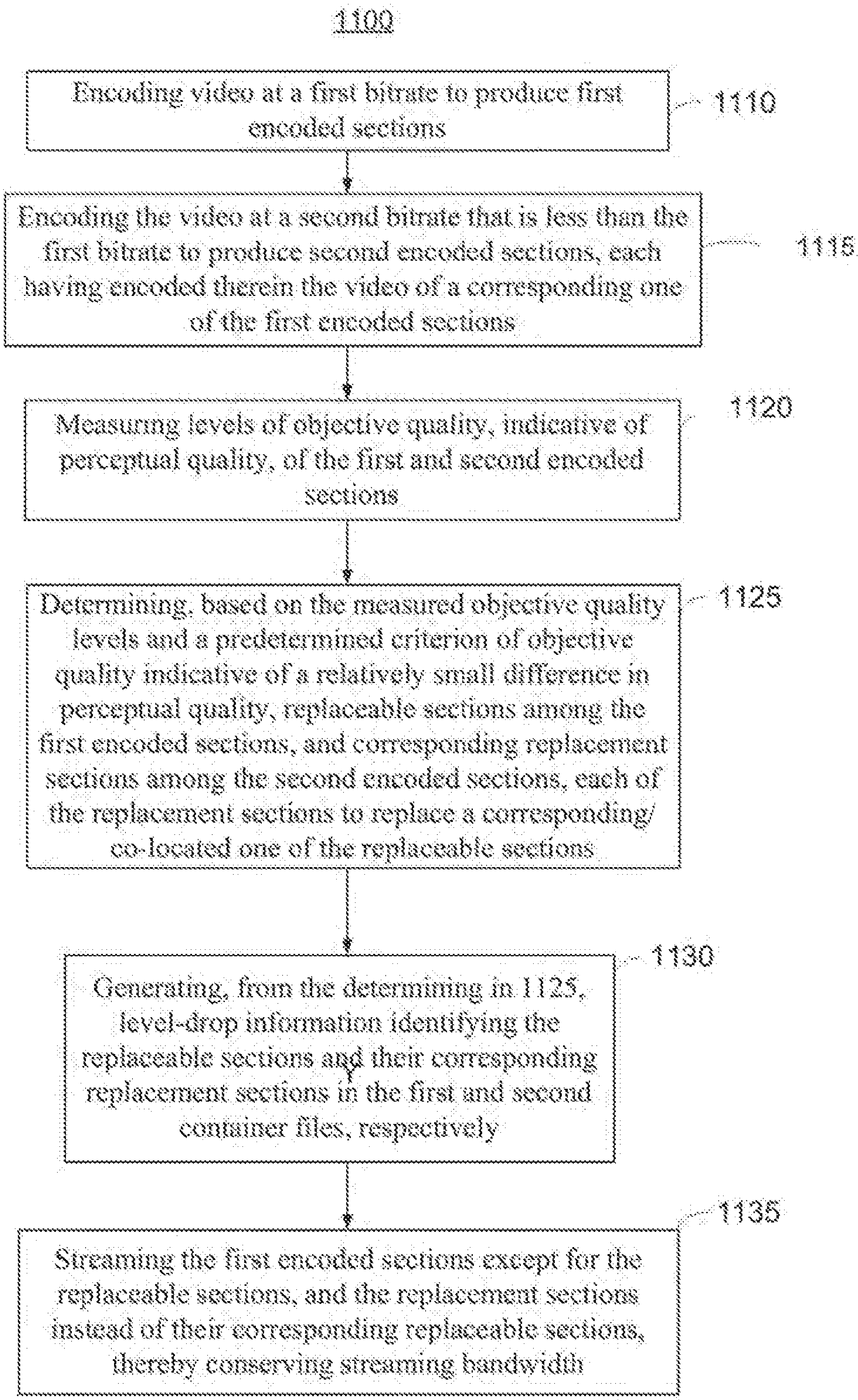

1100
Encoding video at a first bitrate to produce first encoded sections
1110
Encoding the video at a second bitrate that is less than the first bitrate to produce second encoded sections, each having encoded therein the video of a corresponding one of the first encoded sections
1115
Measuring levels of objective quality, indicative of perceptual quality, of the first and second encoded sections
1120
Determining, based on the measured objective quality levels and a predetermined criterion of objective quality indicative of a relatively small difference in perceptual quality, replaceable sections among the first encoded sections, and corresponding replacement sections among the second encoded sections, each of the replacement sections to replace a corresponding/co-located one of the replaceable sections
1125
Generating, from the determining in 1125, level-drop information identifying the replaceable sections and their corresponding replacement sections in the first and second container files, respectively
1130
Streaming the first encoded sections except for the replaceable sections, and the replacement sections instead of their corresponding replaceable sections, thereby conserving streaming bandwidth
1135

FIG. 11

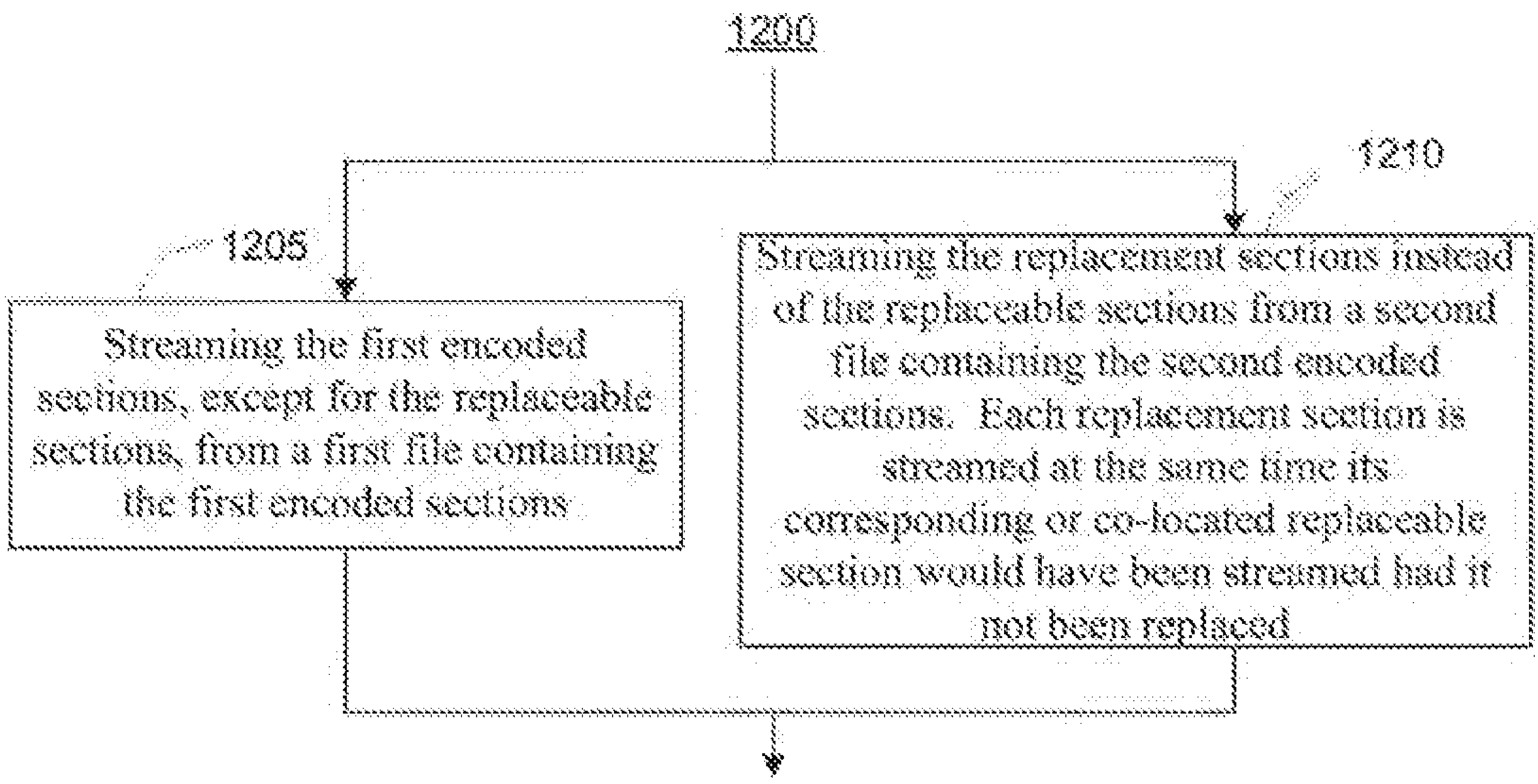

1200
1205
Streaming the first encoded sections, except for the replaceable sections, from a first file containing the first encoded sections
1210
Streaming the replacement sections instead of the replaceable sections from a second file containing the second encoded sections. Each replacement section is streamed at the same time its corresponding or co-located replaceable section would have been streamed had it not been replaced

FIG. 12

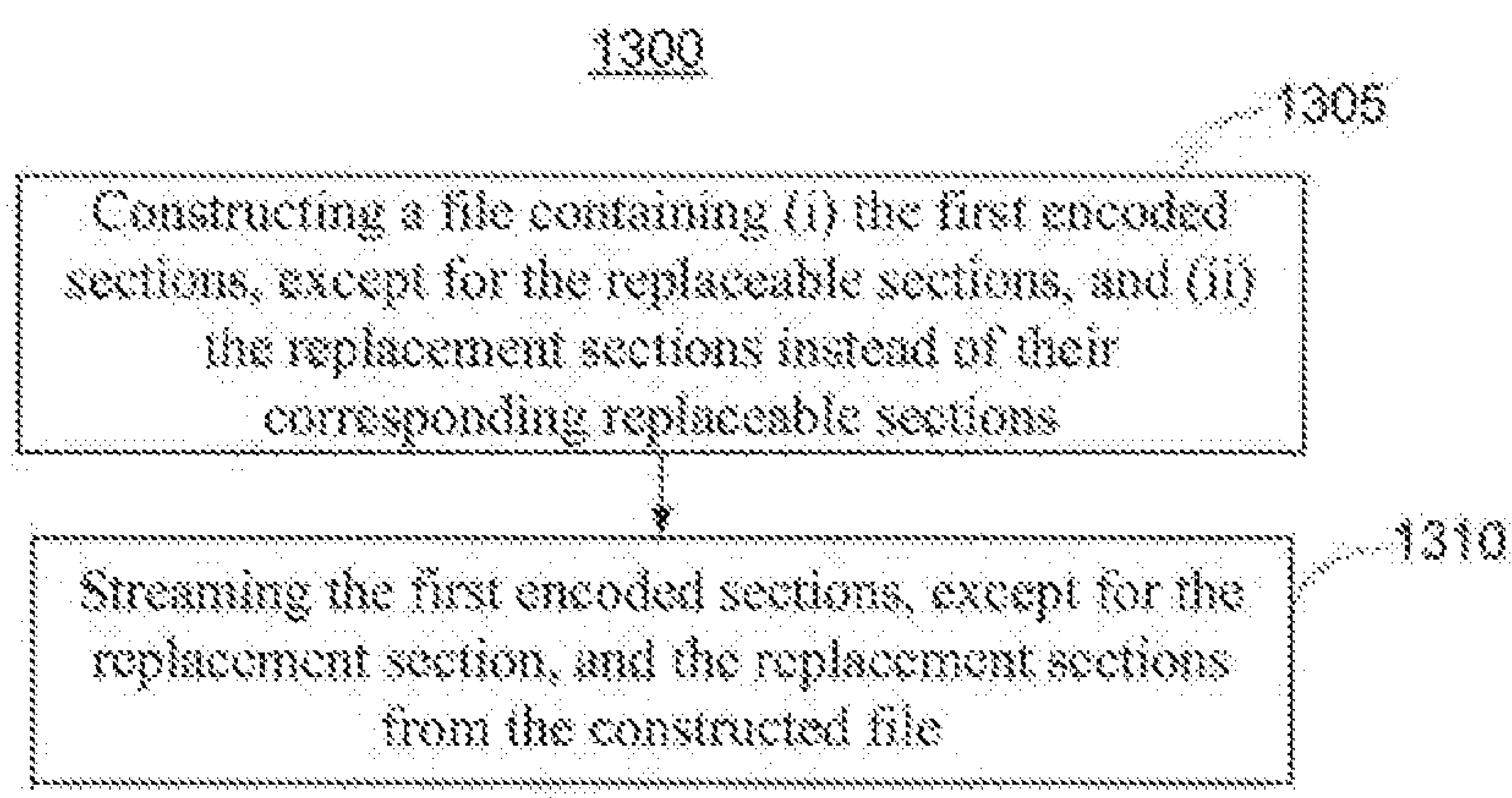

1300
1305
Constructing a file containing (i) the first encoded sections, except for the replaceable sections, and (ii) the replacement sections instead of their corresponding replaceable sections
1310
Streaming the first encoded sections, except for the replacement section, and the replacement sections from the constructed file

FIG. 13

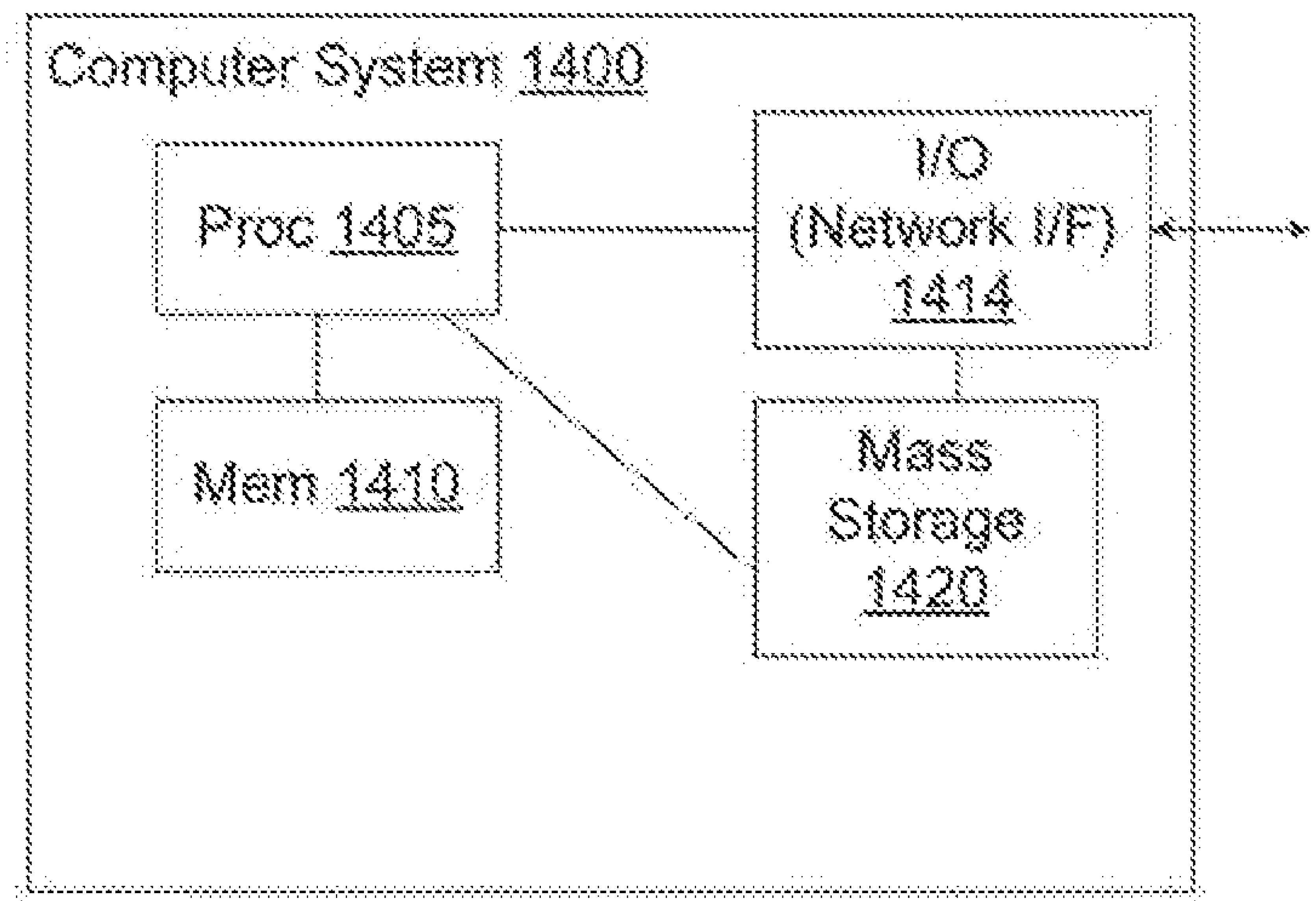

Computer System 1400
Proc 1405
I/O (Network I/F) 1414
Mem 1410
Mass Storage 1420

FIG. 14

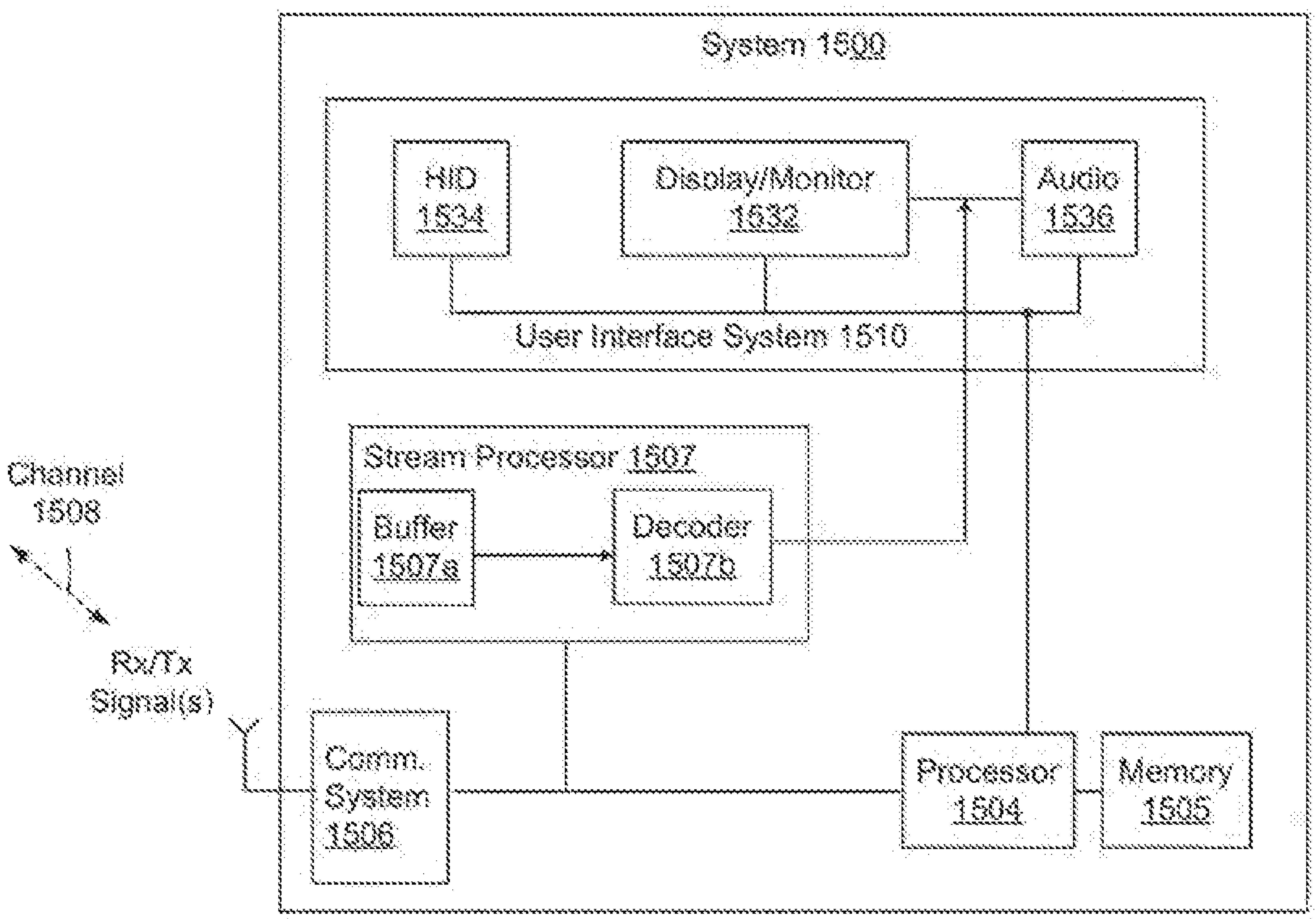
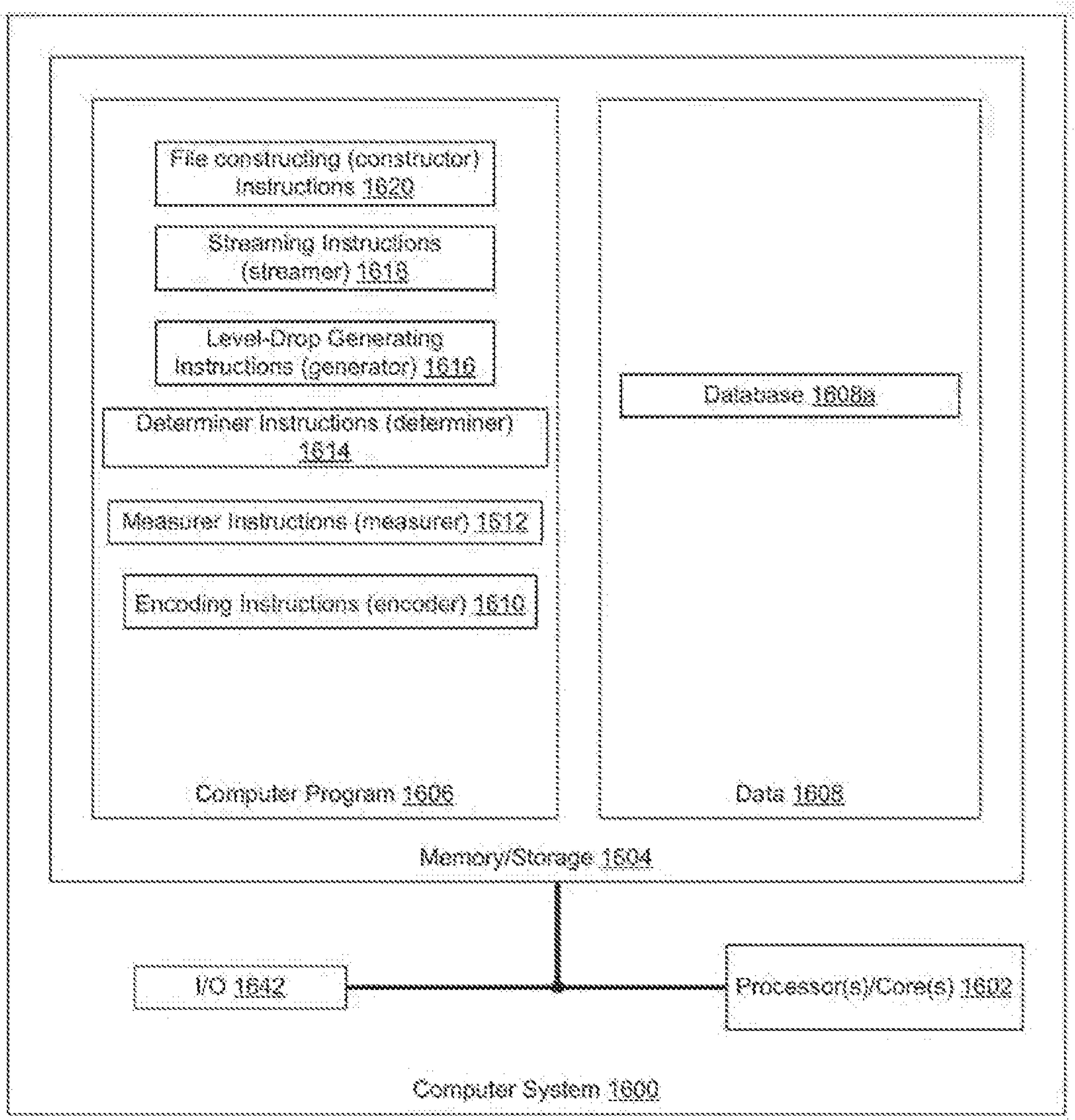
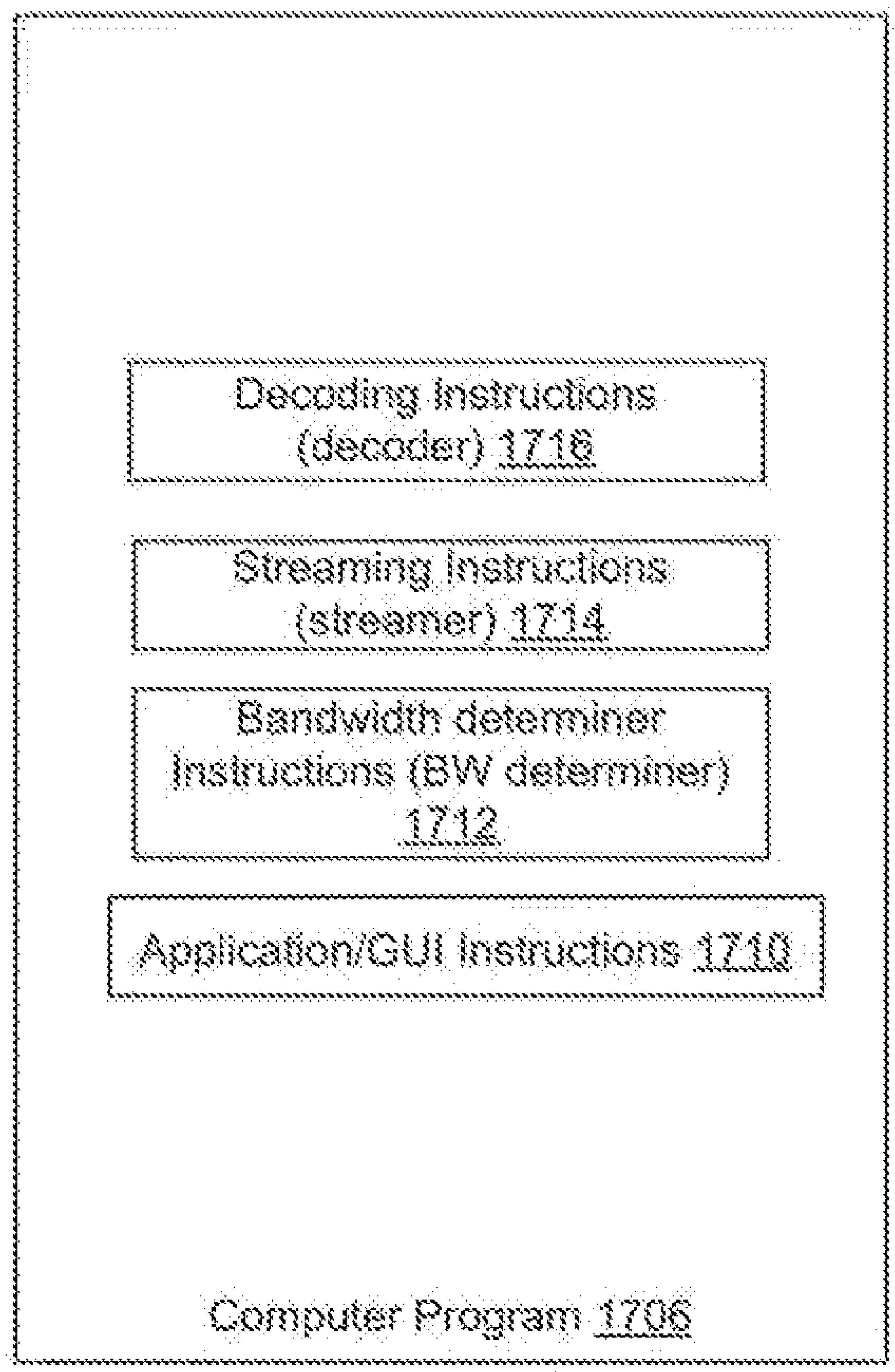

System 1500
HID 1534
Display/Monitor 1532
Audio 1536
User Interface System 1510
Stream Processor 1507
Buffer 1507a
Decoder 1507b
Channel 1508
Rx/Tx Signal(s)
Comm. System 1506
Processor 1504
Memory 1505

FIG. 15



File constructing (constructor) Instructions 1620
Streaming Instructions (streamer) 1618
Level-Drop Generating Instructions (generator) 1616
Determiner Instructions (determiner) 1614
Measurer Instructions (measurer) 1612
Encoding Instructions (encoder) 1610
Computer Program 1606
Database 1608a
Data 1608
Memory/Storage 1604
I/O 1642
Processor(s)/Core(s) 1602
Computer System 1600

FIG. 16



Decoding Instructions (decoder) 1716
Streaming Instructions (streamer) 1714
Bandwidth determiner Instructions (BW determiner) 1712
Application/GUI Instructions 1710
Computer Program 1706

FIG. 17

USE OF OBJECTIVE QUALITY MEASURES OF STREAMED CONTENT TO REDUCE STREAMING BANDWIDTH

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue; a claim printed with strikethrough indicates that the claim was canceled, disclaimed, or held invalid by a prior post-patent action or proceeding.

BACKGROUND

Distribution of multimedia (also referred to herein as "media" and/or "program(s)"), such as movies and the like, from network services to a client device may be achieved through adaptive bitrate streaming of the media. Typically, the media may be encoded at different bitrates and resolutions into multiple bitrate streams that are stored in the network services. Conventional adaptive bitrate streaming of media includes determining streaming conditions, e.g., an available streaming bandwidth at the client device, and then streaming a selected one of the different bitrate stream from the network services to the client device based on the determined conditions.

From the perspective of the network service, streaming media includes transmitting the media in response to requests from the client device. From the perspective of the client device, streaming media includes continuously requesting and receiving the media from the network services, and storing the received media in a buffer for subsequent presentation or playback, essentially, in near real-time. The buffered media may be presented, i.e., played back, in audio-visual form, for example.

The human visual system perceives a perceptual or subjective quality of streamed, presented media, and is able to detect small changes in the perceptual quality. The perceptual quality generally increases and decreases as the encoded bitrate of the streamed program (i.e., "streaming bitrate") increases and decreases. Therefore, more or less available streaming bandwidth may translate to more or less perceptual quality, respectively.

Given the ever pressing need to conserve bandwidth at the client device, conventional streaming techniques tend to select a streaming bitrate deemed to be sufficiently high to meet an acceptable level of perceptual quality, based on the streaming bandwidth conditions determined at the client device, as mentioned above. This bandwidth-centric determination and selection at the client device dies not take into consideration changes or variations in the content contained in the media itself over time as the media is streamed and, therefore, often results in unnecessarily high, and therefore, bandwidth-wasteful, streaming bitrates.

BRIEF DESCRIPTION OF THE DRAWINGS/FIGURES

FIG. **1** is a block diagram of an example network environment in which adaptive streaming of multimedia (also referred to herein as "media" and "program(s)") from network services to a client device may be implemented.

FIG. **2** is an illustration of an example encoded video program generated by a media distributor.

FIG. **3** is an illustration of a container file that encodes a single audio stream.

FIG. **4** is an illustration of a container file that encodes multiplexed audio and video streams.

FIG. **5** is an illustration of a container file that encodes multiplexed video, audio, text, and metadata streams.

FIG. **6** is an illustration of an example of swapping-while-streaming from the container files of FIG. **2**.

FIG. **7** is an illustration of an example of pre-swapped streaming using the container files of FIG. **2**.

FIG. **8** is an illustration of example level-drop (or swap) information that identifies swappable, co-located clusters, as determined in cluster swapping examples of FIGS. **6** and **7**.

FIG. **9** is a sequence diagram of example high-level interactions between a distributor and a client device in the network environment of FIG. **1**.

FIG. **10** is a flowchart of an example method of streaming a program, which may be performed at a client device of FIG. **1**.

FIG. **11** is a flowchart of an example method of adaptive streaming of programs from network services to a client device, which may be performed in a distributor of the network services.

FIG. **12** is a flowchart of a method expanding on the streaming in the method of FIG. **11** corresponding to a swapping-while-streaming embodiment, in which streaming is from multiple files.

FIG. **13** is a flowchart of a method expanding on the streaming of the method of FIG. **11**, corresponding to a pre-swapped embodiment, in which streaming is from a single file constructed from multiple different files.

FIG. **14** is a block diagram of an example computer system corresponding to any network services, including a distributor in the network services.

FIG. **15** is a block diagram of an example system representing a client device.

FIG. **16** is a block diagram of a computer system configured to perform processing of media/programs and adaptive streaming.

FIG. **17** is a block diagram of an example computer program hosted in a client-side computer system (e.g., client device) similar to the compute system of FIG. **14**.

In the drawings, the leftmost digit(s) of a reference number identifies the drawing in which the reference number first appears.

DETAILED DESCRIPTION

Embodiments described herein are directed to adaptive streaming of a video program from network services to a client device that utilize encoded video section swapping to reduce streaming bandwidth, which minimally impacting a perceptual/presentation quality of the streamed program at the client device. The adaptive streaming with sections swapping embodiments reduce streaming bandwidth at client the device based on characteristics or properties of content in the video program, i.e., measures of objective quality indicative of perceptual quality, that changes over time while the program is being streamed. More specifically, the embodiments determine swappable, corresponding/co-located sections of video encoded at different bitrates based on the measured objective quality levels of the co-located sections and the predetermined criterion of objective quality. The swappable, co-located sections include a section encoded at a first bitrate and a section encoded at a second bitrate that is less than the first bitrate. During streaming of the video program, the section encoded at the first bitrate is replaced with the co-located section encoded at the lesser second bitrate, thereby conserving streaming bandwidth by a substantial amount approximately equally to a difference between the first and second bitrates.

Network Environment

FIG. **1** is a block diagram of an example network environment **100** in which adaptive streaming of programs from network services to a client device may be implemented. Network environment **100** includes a collection of server-side services **101** that interact and cooperate to originate, manage, and distribute, e.g., stream, programs to a user operated client device **104** over one or more networks **106**, such as the Internet. Such program include, but are not limited to, entertainment programs (e.g., television, shows, movies, cartoons, new programs, etc.), educations programs (e.g., classroom video, adult education video, learning programs, etc.), and advertising programs (e.g., commercials, infomercials, or marketing content). Network services **102** communicate with each other and with client device **104** using any suitable communication protocol, such as an Internet protocol, which may include Transmission Control Protocol/Internet Protocol (TCP/IP), Hypertext Transfer Protocol (HTTP), etc.

Client device **104** may be capable of wireless and/or wired communication with networks **106**. Client device **104** includes processing, storage, communication, and user interface capabilities sufficient to provide all of the client device functionality described herein. Such functionality may be provided, at least in part, by one or more applications, such as computer programs, that execute on client device **104**. Applications executed on client device **104** may include client-side application, which presents Graphical User Interfaces (GUIs) through which a user of the client device may interact with and request services from corresponding server-side applications hosted in services **102**. Accordingly, under user control, client device **104** may request/select programs from services **102**, stream the selected programs from the services, and then present the streamed programs, in other words, playback the streamed programs.

Network services **102** include, but are not limited to, one or more media provider(s) **112** to originate source programs, and one or more media distributor(s) **114** to encode, store, and distribute the programs to client device **104**. Each of the services **102** may be implemented as one or more computer servers that execute one or more associated server-side computer program applications suited to the given service. Media providers **112**, such as Netflix®, HBO®, cable networks, and so on, utilize network services **102** to manage and deliver their revenue bearing programs to client device **104**. Media providers **112** download their source programs to distributor **114**, which encodes, stores, and then streams the encoded programs to client device **104** when requested to do so.

Distributor **114** includes an encoded **122** and a stream manager **126**. Encoded **122** may encode each program into a number of alternative streams to support adaptive bitrate streaming of the program. The alternative streams encode the same program in different ways, such as at one or more of different bitrates, one or more different resolutions, and/or one of more different frame rats. As will be described more fully below in connection with FIG. **2**, each of the encoded streams is typically stored in one or more container files. Encoder **122** also generates a program index file for the container files associated with the encoded program. Stream manager **126** manages streaming of the encoded program from the container files to client device **104** when the client device requests the program. Stream manager **126** cooperates with the requesting client device **104** to support adaptive bitrate streaming of the program from the container files to the client device.

Distributor **114** may also store auxiliary streams which contain information associated with the program streams mentioned above. The auxiliary streams are encoded at low bitrates, e.g., at bitrates of 200 kbps or much less. The auxiliary streams may include metadata synchronized in time with and descriptive of the content in associated main program streams. The metadata may include cues indicating or bracketing, e.g., commercial segments, or other non-program segments/content, such as level-drop information for encoded section swapping as will be described below, interspersed throughout the program streams. Typically, such auxiliary streams would be streamed simultaneously with their associated program streams and handled appropriately at the client device. However, the auxiliary streams may be streamed before the program streams.

As discussed above, client-side GUIs provide a user with access to services and program offerings. Such client-side GUIs typically include easily navigable program guides, and may present programs and channel selection options, program descriptions, advertisements, programming/user control options, and other typical programming features, as would be appreciated by those of ordinary skill in the relevant arts. The client-side GUIs accept user selections/requests, such as a request to view a program. In response to such GUI selections/requests, the client-side application sends appropriate requests to a counterpart server-side application residing in distributor **114**, to initiate the appropriate actions among services **102** that will satisfy the client selections/requests, e.g., enable a client device to stream the selected program from the distributor for presentation to the user.

Container Files—Streaming Sources

As described above, distributor **114** encodes source programs from providers **112**. To support adaptive bitrate streaming, distributor **122** may encode the source programs at multiple bitrates to produce multiple streams for each source program, as will be described more fully below in connection with FIG. **2**. While streaming such encoded programs, client device **104** may switch between streams (and thus between encoded bitrates and corresponding streaming rates) according to conditions at the client device.

FIG. **2** is an illustration of an example encoded video program **200** generated by distributor **112**. Encoded video program **200** includes multiple (encoded) video streams 1-4 encoded at multiple corresponding bitrates Rate 1-Rate 4. Encoded video streams 1-4 encode video at multiple video resolutions Res 1-Res 4, which may be equal to or different from each other. Encoded video program **200** includes a program stream index **204** and multiple container files **208(1)-208(4)** corresponding to streams 1-4.

Program stream index **204** includes pointers **210(1)-(4)**, e.g., Uniform Resource Locators (URLs), to corresponding container files **208(1)-(4)**, and lists encoding parameters used to encode each of the streams 1-4, including, but not limited to, encoded bitrates Rate 1-Rate 4, encoding resolutions Res 1-Res 4, frame rates, and encoding techniques/standards. Exemplary, non-limiting, bitrates may range from below 125 kilo-bits-per-second (kbps) up to 15,000 kbps, or even higher, depending on the type of encoded media.

Each of container files **208** comprises sequential clusters **212** of a larger media sector (not shown in FIG. **2**), and sequential blocks **214** of encoded media (which may also include audio, text, multimedia, etc., in addition to video) within each of the clusters. Each cluster **212**, and each block

214, includes a time code TC indicating a start time for the media encoded in the blocks of that cluster, and encodes a fixed duration of media. For example, each cluster **212** of container file **208**(**1**) encodes two seconds of video. In other embodiments, each cluster may encode a different duration of media, which may vary from two seconds. Each cluster **212** is a self-contained unit of media that may be decoded and presented on client devices **204** without reference to any other clusters. Clusters **212** may also include successive cluster members identifying a streaming sequence of the clusters.

Each cluster/block **212**/**214** in a given one of the container files **208** encodes the same content (e.g., video content) as corresponding clusters in the other ones of the container files. For example, the cluster/block indicated at A in container file **208**(**1**) has encoded therein the same video as that encoded in the clusters/blocks indicated at B, C, and D of container files **208**(**2**), **208**(**3**), and **208**(**4**), respectively. Corresponding clusters/blocks are also referred to herein as "co-located" clusters/blocks because they encode the same video and share the same time code TC, i.e., they are aligned or coincide in time.

Container files may encode a single stream, such as a video stream (as depicted in FIG. **2**), an audio stream, or a text stream (e.g., subtitles). Alternatively, each container file may encode multiple multiplexed streams, such as a mix of video, audio, and text streams. FIGS. **3**-**5** are further illustrations of diverse container files.

FIG. **3** is an illustration of a container file **300** that encodes a single audio stream.

FIG. **4** is an illustration of a container file **400** that encodes multiplexed audio and video streams.

FIG. **5** is an illustration of a container file **500** that encodes multiplexed video, audio, text, and metadata streams.

In addition, a container file may encode only a metadata stream at a relatively low bitrate.

The encoded container files depicted in FIGS. **2**-**5** support adaptive streaming to client device **104**. If conditions change while streaming, then client device **104** may switch between container files to stream at rates best suited to the conditions.

In embodiments: the container files may be Matroska containers based on Extensible Binary Meta Language (EBML), which is a derivative of Extensible Binary Meta Language (XML), or files encoded in accordance with the Moving Picture Experts Group (MPEG) standard; the program index may be provided in a Synchronized Multimedia Integration Language (SMIL) format; and client device **104** may implement adaptive streaming from distributor **114** over networks **106** using the HTTP protocol.

The container files described above may support adaptive streaming of encoded video programs across an available spectrum bandwidth that is divided into multiple, i.e., n, levels. Video having a predetermined video resolution for each level may be encoded at a bitrate corresponding to the band-width associated with the given level. For example, in DivX® Plus Streaming, by Royi Corporation, the starting bandwidth is 125 kbps and the ending bandwidth is 8400 kbps, and the number n of bandwidth levels is eleven (11). Each bandwidth level encodes a corresponding video stream, where the maximum encoded bitrate of the video stream (according to a hypothetical reference decoder model of the video coding standard H.264) is set equal to the bandwidth/bitrate of the given level. In DivX® Plus Streaming, the 11 levels are encoded according to 4 different video resolution levels, in the following way: mobile (2 levels). standard definition (4 levels), 720p (2 levels), and 1080p (3 levels).

Section Swapping: Objective Quality vs. Perceptual Quality

Adaptive streaming embodiments described herein take into consideration certain characteristics in the content in video programs (also referred to herein simply as "video") to be streamed, to reduce streaming bitrates. as will now be described. The human visual system is able to detect small changes in the perceptual or presentation quality of presented video. However, perceptual quality and changes in perceptual quality are difficult to measure directly. Instead, certain characteristics or properties of encoded video, that are indicative of perceptual quality video as actually presented (i.e., once the encoded video is decoded and presented), may be determined, e.g., measured directly, in a straight forward manner. Such measured properties represent an objective quality of the video. As the content of encoded video varies across successive sections of the encoded Video, and between co-located sections of encoded video in different video streams, the objective quality correspondingly varies, and may be measured to determine a level of objective quality corresponding to each of the aforementioned sections. The term "section" as used herein refers to a number of successive frames of video, including, but not limited to, multimedia audio-visual content, which may be collected into successive blocks and clusters in container files for streaming, as described above.

The difference in objective quality levels between co-located sections of encoded video (e.g., between co-located clusters from two container files that encode the same video but at different bitrates) may be used to determine a corresponding difference in the perceptual quality of the two video sections. Specifically, the difference in objective quality levels may be used to determine whether that difference is sufficiently large as to cause a visually noticeable difference in the perceptual quality of the two sections (once decoded and presented). With this in mind, there exists a criterion of objective quality (referred to as a predetermined "swap criterion" of objective quality), for the two objective quality levels, that translates to a virtually imperceptible difference in perceptual quality. Two co-located sections having objective quality levels that meet this criterion are considered interchangeable or swappable with each other for purposes of streaming to a client device because of their imperceptible or nearly imperceptible difference in perceptual quality. "Co-located" sections are also referred to herein as "corresponding" sections.

Swappable, co-located, encoded sections may be swapped to reduce streaming bandwidth in cases where co-located sections include a first section encoded at a relatively high bitrate and a (co-located) second section encoded at a relatively low bitrate. Specifically, streaming the (lower bitrate) second section instead of (i.e., in place of) its co-located (higher bitrate) first section reduces streaming bandwidth, while maintaining perceptual quality. The first section is referred to herein as a "replaceable section" and the second section that is streamed instead of the first section is referred to herein as the "replacement section." The more often high bitrate sections are replaced with their co-located low bitrate sections while streaming, i.e., the more often bitrate swapping occurs, the more streaming bandwidth is conserved.

Measures of objective quality of a section of encoded video (e.g., of a cluster/block of encoded video) include, but are not limited to, a signal-to-noise ratio (SNR) of the section, a peak SNR (PSNR) of the section, a structural similarity index (SSIM) that measures a similarity between sections, and so on.

PSNR is a commonly used measure for assessing a quality of reconstructed video after compression (encoding). PSNR is measured on a logarithmic scale and depends on the Mean Squared Error (MSE) between an original source image and an impaired image or video frame. A higher PSNR generally indicates better quality, while a lower PSNR generally indicates poorer quality. Formulas for PSNR are given below:

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i, j) - K(i, j)]^2$$

$$PSNR = 10 \cdot \log_{10}(MAX_i^2 / MSE)$$

Where: m & n are dimensions of an image; I & K are components of an image (Y, U, V); and MAX_i is a maximum possible pixel value.

Each section of encoded video may be assigned one or more scores based on the different possible objective quality measures. Multiple successive encoded sections may have their objective quality levels combined into and, therefore, associated with, a single measurement of objective quality, which may include, e.g., a mean or variance of the SNR (or PSNR) or each of the multiple sections.

A criterion of objective quality that indicates co-located sections may be swapped with little or no impact on perceptual quality—if the co-located section have levels of objective quality that each meet that criterion—may be based on one of:

a. an absolute level of objective quality, e.g., co-located clusters are declared swappable if the PSNR of each cluster is above a threshold PSNR; and
b. a difference between respective levels objective quality of co-located encoded sections, e.g., co-located clusters are declared swappable if a difference between their respective PSNR values is less than a certain PSNR difference threshold.

For relative criterion (b), a variable scale may be defined using as a base PSNR a highest level PSNR among encoded sections under consideration; e.g., for encoded section PSNR levels in a range of 29 dB and 31 dB, an acceptable difference value may be 1.5 dB, and for encoded section PSNR levels in a range of 27 dB and 29 dB, an acceptable PSNR difference level may be only 1 dB. The variable scale may be extended to cover all encoded section PSNR levels that are expected as part of an encoding process, and may also extend to cover other objective quality metrics such as a mean, a variance, a difference between highest and lowest PSNR levels in a cluster, or a formula combining some or all of these or other metrics. Such assignments may be altered based on the type of objective quality that is used.

Embodiments directed to adaptive streaming using section swapping described below include (i) a "swapping-while-streaming" embodiment in which swappable co-located sections from different files are swapped while streaming, and (ii) a "pre-swapped streaming" embodiment in which a single file containing pre-swapped sections is constructed from multiple encoded files before streaming is initiated, and then all of the sections in the single file, including the pre-swapped sections, are streamed from that file. Examples of these embodiments are described below.

Swapping-While-Streaming

In swapping-while-streaming, swappable co-located sections are swapped while streaming from multiple different container files in real-time, such as from multiple container files **208** in FIG. **2**.

FIG. **6** is an illustration of an example of swapping-while-streaming from container files **208** of FIG. **2**. With reference to FIG. **6**, the example assumes the following:

a. Separate container files **208(1)**, **208(2)**, and **208(3)** represent three levels N, N−1 and N−2, respectively, of the n levels available for e.g., DivX® Plus Streaming;
b. Levels N, N−1, and N−2 are each encoded at successively decreasing bitrates but may be at the same resolution. In other examples, the Levels are each encoded at successively decreasing bitrates but may be at different resolutions;
c. Swappable, co-located clusters (including a replaceable section, and its corresponding replacement section) have been determined and identified across the container files **208(1)**-**208(3)**. As described above, the swappable, co-located clusters are determined based on determined/measured objective quality levels of the clusters in the container files and a comparison of the determined/measured objective quality levels (of co-located sections) against a predetermined criterion of objective quality indicative of a minimal difference in perceptual quality; and
d. Level N is initially selected for streaming.

Traversing left-to-right in FIG. **6**, initially, encoded sections from level N are streamed from container file **208(1)**. Encoded sections are streamed predominantly from level N. However, while the sections from Level N are streamed, replaceable (swappable) sections thereof are encountered and replaced with co-located replacement (swappable) sections from level N−1, or level N−2, as indicated at LD1, or LD2, respectively. That is, the lower level, co-located replacement sections are streamed instead of the higher level replaceable sections, resulting in conserved streaming bandwidth. Each replacement section is streamed at the same time its corresponding co-located replaceable section would have been streamed had it not been replaced, so as to maintain a proper encoded video sequence. A section swap is referred to as a "level-drop" because the source level (n) from which the replacement section is streamed is lower than the current level, e.g., in a swap, the level drops from level N to Level N−1, or Level N−2. In swapping while streaming, client device **104** and distributor **114** cooperate with each other to swap sections from different container files.

Pre-Swapped Streaming

In pre-swapped streaming, a single file containing swappable sections, i.e., level-drops, is constructed from multiple files before streaming. Then, the sections in the single file, including the pre-swapped sections, are streamed from that file.

FIG. **7** is an illustration of an example of pre-swapped streaming using container files **208** of FIG. **2**. Before streaming, swappable, co-located clusters are determined and identified across levels N, N−1, and N−2, similar to the swapping-while-streaming embodiment. The determined swaps, or level-drops, are incorporated into Level N. In other words, determined and identified replaceable sections of Level N are replaced with co-located replacement sections of Levels N−1 and N−2, as identified. As a result, a new, pre-swapped Level N file is constructed that incorporates original sections of Level N that were not indicated as replaceable, and the determined/identified replacement sections (i.e., level-drops) instead of the replaceable sections. Then, sections are streamed only from the new, pre-swapped Level N file. In pre-swapped streaming, streaming of the pre-swapped sections is transparent to client device **104**, which simply requests streaming sections from the single file. The examples of FIGS. **6** and **7** may be extended over more container files at different bitrates, and thus more levels and corresponding level-drops.

Level-Drop Information

FIG. **8** is an illustration of example level-drop (or swap) information **800** that identifies swappable, co-located clusters, as determined in the cluster swapping examples of FIGS. **6** and **7**. In the manner described above, and further below, distributor **114** measures objective quality levels of sections, e.g., clusters in container files **208**, and then determines swappable co-located clusters between the files based on the measured objective quality levels and a predetermined swap criterion. Distributor **114** generates level-drop information **800** as records **802**, **804** and **806** that identify the determined, swappable, co-located clusters in the different files. Each record identifies swappable clusters including a starting cluster and its contiguous following clusters (if any), and also blocks within clusters. Each record may include one or more of cluster/block numbers, time codes TC, location/addresses of the clusters in the file. Level-drop information **800** includes:

a. records **802** linked vertically to indicate determined, time-ordered, replaceable clusters among the clusters of level N, e.g., in container file **208**(**1**);
b. records **804** linked vertically to indicate determined, time-ordered replacement clusters among the clusters of level N−1, e.g., in container file **208**(**2**); and
c. records **806** to indicate a determined replacement cluster among the clusters of level N−2, e.g., in container file **208**(**3**).

Horizontal links **810** between records indicating co-located, replaceable and replacement clusters, e.g., between Level N and Levels N−1, N−2.

Distributor **114** may embed level-drop information **800** as in container files and metadata. Alternatively, or additionally, level-drop information may be stored as an auxiliary/metadata, level-drop file that is stored and indexed separately from the container files. Therefore, in the swapping-while-streaming embodiment, level-drop information **800** may be streamed from distributor **114**, to client device **104**, with streamed clusters. Alternatively, level-drop information may be streamed from the auxiliary file separately from the clusters.

In the pre-swapped embodiment, distributor **114** uses level-drop information **800** to construct a single pre-swapped file and need not be streamed to client device **104**. However, client device **104** does not need the level-drop information.

Server-Client Sequence Diagram

FIG. **9** is a sequence diagram of example high-level interactions **900** between distributor **114** and client device **104** in network environment **100**. Interactions **900** progress in time from top-to-bottom in FIG. **9**, as a sequence of phases beginning with an initialization/set-up phase **904** indicated in the top left-hand corner of FIG. **9**.

During initialization/set-up phase **904**, distributor **114** encodes video programs and stores the encoded video programs in container files for subsequent streaming to client device **104**. Distributor **114** determines swappable co-located sections among the container files associated with each program based on determined objective quality measures and a predetermined swap criterion for the objective quality measures of co-located clusters in different files, as discussed above. Distributor **114** embeds drop-level information, such as information **900**, in the container files, or stores the information in a separate drop-level file. In the pre-swapped embodiment, distributor **114** constructs a single file for streaming using the drop-level information and the multiple container files.

During a user interaction phase **920**, client device **104** presents client-side GUIs to a user. At **924**, the user selects a program from the GUIs, and, in response, client device **104** sends a request for the program to distributor **114**.

During a pre-streaming phase **930**, in response to the client device request (at **924**), at **932**, the distributor **114** sends an index of URLs associated with the requested program to client device **104**. In the swapping-while-streaming embodiment, distributor **114** may also sends drop-level information if such information is provided in a separate file. Alternatively, distributor **114** may stream the drop-level information to client **104** in subsequent pre-streaming and streaming phases **930**, **940**, described below. The URLs may include a first URL directed to a program index (e.g., index **204** in FIG. **2**) for the encoded program corresponding to the requested program and stored in distributor **114**, and a second URL directed to a drop-level file, if available.

During streaming phase **940**, streaming of the requested program from distributor **114** to client device **104** commences. Client device **104** determines a streaming bandwidth available at the client device and selects a stream from among the multi-bitrate streams, as indicated in the program index, that best matches the determined bandwidth. Client device **104** continually requests encoded stream sections from container files in distributor **114** based on the index information and the level-drop information (in the swapping-while-streaming embodiment), and receives the requested blocks from the distributor. In the swapping-while-streaming embodiment, the level-drop information may have been received during pre-streaming phase **930**, may be streamed from a separate level-drop file, and/or may be embedded as records in the encoded video sections streamed during stage **940**. Client device **104** buffers the received sections, decodes the buffered sections, and then presents the decoded sections. As streaming conditions change, client device **104** may switch to a new stream, i.e., request sections from another stream having a bitrate better suited to the changed conditions.

In yet another embodiment, level-drop information may be calculated dynamically at client device **104** instead of distributor **114** based on objective quality levels embedded in streamed sections. In this embodiment, distributor **114** embeds measured objective quality levels in corresponding encoded video sections, and streams the sections to the client device **104**. Client device **104** calculates level-drop information based on the received objective quality levels, and performs swapping-while-streaming based on the dynamically calculated objective quality levels.

In both the swapping-while-streaming and pre-swapped embodiments, client device **104** intermittently requests replacement blocks having a lower encoded bitrate than the co-located replaceable block, which advantageously conserves streaming bandwidth at the client device. Each replacement block is streamed at the same its corresponding or co-located replaceable block would have been streamed had it not been replaced.

Client-Side Method

FIG. **10** is a flowchart of an example summary method **1000** of stream a video program with swapped sections, which may be performed at client device **104**.

1005 includes requesting to stream the video program.

1010 includes receiving an index to multiple files containing the video encoded at different bitrates, including at least a first bitrate and a second bitrate that is less than the first bit rate.

1015 includes determining an available streaming bandwidth.

1020 includes selecting from the received index the file encoded at the first bitrate based on the determined streaming bandwidth.

1025 includes initiating streaming of the selected file.

1030 includes streaming the selected file, including requesting successive sections of encoded video and receiving the requested sections. The swapping-while-streaming embodiment also includes receiving level-drop information in any number of ways, including streaming the level-drop information from an auxiliary file before or while streaming the encoded video, or as metadata embedded with the streamed encoded sections. The streaming in the swapping-while-streaming embodiment includes requesting encoded sections from multiple levels (e.g., levels N, N−1, and N−2, etc.), i.e., requesting swappable sections, based on the level-drop information, so as to conserve bandwidth.

Server/Network-Side Method

FIG. **11** is a flowchart of an example summary method **1100** of preparing, and adaptive streaming of, a video program with swapped sections from services **102** to client device **104**, which may be performed in distributor **114**.

1110 includes encoding video at a first bitrate to produce first encoded sections.

1115 includes encoding the video at a second bitrate that is less than the first bitrate to produce second encoded sections, each having encoded therein the video of a corresponding one of the first encoded sections. The first and second encoded sections may encode video that has the same resolution for each of the first and second encoded sections, or may encode video having different resolution.

1120 includes measuring levels of objective quality, indicative of perceptual quality, of the first and second encoded sections.

1125 includes determining, based on the measured objective quality levels and a predetermined criterion of objective quality indicative of a relatively small difference in perceptual quality, swappable sections, including replaceable sections among the first encoded sections, and corresponding replacement sections among the second encoded sections, each of the replacement sections to replace a corresponding/co-located one of the replaceable sections. This can be through of as declaring or identifying certain co-located sections as swappable sections if they meet the predetermined criterion. A result of the determining in **1125** is to identify sections in lower levels (e.g., N−1, N−2) which may be swapped with higher levels (e.g., N) with little or no impact to the subjective/perceptual quality of the video.

1130 includes generating, from the determining in **1125**, level-drop information identifying the replaceable sections and their corresponding replacement sections in the first and second container files, respectively.

1135 includes streaming the first encoded sections except for the replaceable sections, and the replacement sections instead of their corresponding replaceable sections, thereby conserving streaming bandwidth. Each replacement section is streamed at the same time its corresponding or co-located replaceable section would have been streamed had it not been replaced.

FIG. **12** is a flowchart of a method **1200** expanding on the streaming at **1140**, corresponding to the swapping-while-streaming embodiment described above, in which streaming is from multiple files.

1205 includes streaming the replacement sections instead of the replaceable sections from a second file containing the second encoded sections. Each replacement section is streamed from the second file at the same time its corresponding replaceable section would have been streamed from the first file.

1210 includes streaming the replacement sections from a second file containing the second encoded sections.

FIG. **13** is a flowchart of a method **1300** expanding on the streaming at **1140**, corresponding to the pre-swapped embodiment described above, in which streaming is from a single file constructed from multiple different bitrate files.

1305 includes constructing a file containing (i) the first encoded sections, except for the replaceable sections, and (ii) the replacement sections instead of their corresponding replaceable sections.

1310 includes streaming the first encoded sections, except for the replacement section, and the replacement sections from the constructed file.

Methods and systems disclosed herein may be implemented with respect to one or more of a variety of systems including one or more consumer systems, such as described below with reference to FIGS. **13** and **14**. Methods and systems disclosed herein are not, however, limited to the examples of FIGS. **13** and **14**.

Prototype Example

In a prototype example, a full length feature movie (video program) (2hours and 25 minutes) was encoded at three bitrates: 8400 kbps, 5300 kbps, and 3500 kbps utilizing a 2-pass encoding process at a resolution of 1920×816 pixels and 24 frames per second. The PSNR for each frame was determined against the original source video, and the frames were grouped into clusters of 48 frames, corresponding to 2 seconds of video frames. From here, the lowest PSNR of the frames in a cluster was determined for each cluster, and a minimum PSNR of 40 dB was chosen as the least acceptable objective quality metric for a cluster. If the minimum PSNR for a cluster at a lower level was available, that cluster was swapped for the higher level cluster. This approach was used for 8400 kbps (using 8400 kbps, 5300 kbps, and 3500 kbps), and for 5300 kbps (using 5300 kbps and 3500 kbps). The results were an accumulative bandwidth savings of 36% for an 8400 kbps stream and 18% for a 5300 kbps stream, with minimal impact on perceptual quality.

System and Computer Block Diagrams

FIG. **14** is a block diagram of an example computer system **1400** corresponding to any of services **102**, including distributor **114**. Computer system **1400**, which may be, e.g., a server, includes one or more processors **1405**, a memory **1410** in which instruction sets and databases for computer program applications are stored, a mass storage **1420** for storing, e.g., encoded programs and drop-level information, and an input/output (I/O) module **1415** through which components of computer system **1400** may communicate with networks **106**.

FIG. **15** is a block diagram of an example system **1500** representing, e.g., client device **104**, and may be implemented, and configured to operate, as described in one or more examples herein.

System **1500** or portions thereof may be implemented within one or more integrated circuit dies, and may be implemented as a system-on-a-chip; (SoC).

System **1500** may include one or more processors **1504** to execute client-side application program stored in memory **1505**.

System **1500** may include a communication system **1506** to interface between processors **1504** and communication networks, such as networks **106**. Communication system **1506** may include a wired and/or wireless communication system.

System **1500** may include a stream processor **1507** to process program streams, received over channel **1508** and through communication system **1506**, for presentation at system **1500**. Stream processor **1507** includes a buffer **1507**a to buffer portions of received, streamed programs, and a decoder **1507**b to decode and decrypt the buffered programs in accordance with encoding and encryption standards, and using decryption keys. In an alternative embodiment, decoder **1507**b may be integrated within a display and graphics platform of system **1500**. Stream processor **1507** together with processors **1504** and memory **1505** represent a controller of system **1500**. This controller includes modules to perform the functions of one or more examples described herein, such as a streaming module to stream programs through communication system **1506**.

System **1500** may include a user interface system **1510**.

User interface system **1510** may include a monitor or display **1532** to display information from processor **1504**, such as client-side storefront GUIs.

User interface system **1510** may include a human interface device (HID) **1534** to provide user input to processor **1504**. HID **1534** may include, for example and without limitation, one or more of a key board, a cursor device, a touch-sensitive device, and or a motion and/or image sensor, HID **1534** may include a physical device and/or a virtual device, such as a monitor-displayed or virtual keyboard.

User interface system **1510** may include an audio system **1536** to receive and/or output audible sound.

System **1500** may correspond to, for example, a computer system, a personal communication device, and/or a television set-top box.

System **1500** may include a housing, and one or more of communication system **1506**, processors **1504**, memory **1505**, user interface system **1510**, or portions thereof may be positioned within the housing. The housing may include, without limitation, a rack-mountable housing, a desk-top housing, a lap-top housing, a notebook housing, a net-book housing, a set-top box housing, a portable housing, and/or other conventional electronic housing and/or future-developed housing. For example, communication system **1502** may be implemented to receive a digital television broadcast signal, and system **1500** may include a set-top box housing or a portable housing,, such as a mobile telephone housing.

Accordingly, system **1500** may include, but is not limited to, stand-alone equipment, such as personal computers, lap-tops, ultrabooks, and tablets, and mobile phones and smart-phones/Personal Digital Assistants (PDAs). system **150** may also represent and include a suite of interconnected devices, such a set-top box/video game console device, a remote to operate such a device, and an audio-visual display and/or computer. System **1500** may also represent and include (digital video disk) DVD and Blu-ray players, and televisions.

FIG. **16** is a block diagram of a computer system **1600**, configured to perform processing of media/programs and adaptive streaming as described herein.

Computer system **1600** includes one or more computer instruction processing units and/or processor cores, illustrated herein as processor **1602**, to execute computer readable instructions, also referred to herein as computer program logic.

Computer system **1600** may include memory, cache, registers, and/or storage, illustrated here as memory **1604**, which may include a non-transitory computer readable medium encoded with computer programs, illustrated here as computer program **1606**.

Memory **1604** may include data **1608** to be used by processor **1602** in executing computer program **1606**, and/or generated by processor **1602** during execution of computer program **1606**. Data **1608** includes a database **1608**a of container files and generated drop-level information for use in the methods described herein.

Compute program **1606** may include the following server-side instructions:

a. encoding instructions **1610** to cause processor **1602** to encode programs at different bitrates into different container files;

b. measurer instructions **1612** to measure objective quality levels of encoded video sections;

c. determiner instructions **1614** to cause processor **1602** to determine, based on the measured objective quality levels and a predetermined criterion of objective quality indicative of a relatively small difference in perceptual quality, swappable, co-located sections among the different container files, e.g., to determine replaceable sections and corresponding replacement sections;

d. generating instructions **1616** to generate level-drop information identifying the determined co-located swappable sections;

e. streaming instructions **1618** to stream the encoded programs, and swap the swappable sections as appropriate in the swapping-while-streaming embodiment; and

f. file constructing instructions **1620** to construct a file from multiple files containing pre-swapped sections in the pre-swapped embodiment.

FIG. **17** is a block diagram of an example computer program **1706** hosted in a client-side computer system similar to computer system **1600**. Computer program **1606** may include the following client-side instructions:

a. client-side application instructions **1710** to cause a client-side processor to communicate with corresponding server-side distributors, present corresponding client-side navigable GUIs, permit a user to select programs for presentation, and present streamed programs;

b. bandwidth determiner instructions **1712** to cause the processor to determine an available streaming bandwidth;

c. streaming instructions **1714** to cause the processor to initiate and maintain streaming of programs. Streaming instructions **1714** include instructions to cause the processor to identify swappable co-located sections from drop-level information received from a server-side peer and to stream the identified swappable sections accordingly; and

d. decoding instructions **1716** to cause the processor to decode streamed programs.

Methods and system disclosed herein may be implemented in hardware, software, firmware, and combinations thereof, including discrete and integrated circuit logic, applications specific integrated circuit (ASIC) logic, and microcontrollers, and may be implemented as part of a domain-specific integrated circuit package, and/or a combination of integrated circuit packages. Software may include a computer readable medium encoded with a computer program including instructions to cause a processor to perform one or more functions in response thereto. The computer readable medium may include a transitory and/or non-transitory medium. The processor may include a general purpose instruction processor, a controller, a microcontroller, and/or other instruction-based processor.

Methods and systems are disclosed herein with the aid of functional building blocks illustrating functions, features, and relationships thereof. At least some of the boundaries of these functional building blocks have been arbitrarily defined herein for the convenience of the description. Alternate boundaries may be defined so long as the specified functions and relationships thereof are appropriately performed.

A method embodiment which may be performed at a client-side or a network/server-side comprises:

a. replaceable sections among first sections of video encoded at a first bitrate, and

b. replacement sections of the video each encoded at a bitrate that is less than the first bitrate and having encoded therein the video of a corresponding one of the replaceable sections, each replacement section and the corresponding replaceable section having respective measured levels of objective quality that meet a predetermined criterion of objective quality; and

streaming the first sections of video except for the replaceable sections, and the replacement sections instead of the corresponding replaceable sections.

The method may further comprise:

decoding the streamed first sections and the replacement sections to recover the video encoded therein; and

presenting the recovered video.

In the method, the predetermined criterion of objective quality, if met, may translate to an acceptable difference in perceptual quality levels of the video when decoded from the corresponding replaceable and replacement sections, and then presented.

In the method, the replacement sections may include:

first replacement sections encoded at a second bit rate than is less than the first bitrate; and

second replacement sections encoded at a third bitrate than is less than the second bitrate.

In the method, the streaming may include:

streaming the first sections except for the replaceable sections from a first file containing the first sections and the replaceable sections; and

streaming the replacement sections instead of the replicable sections from a second file containing the replacement sections.

The method may further comprise:

requesting to stream the video;

receiving an index to multiple files containing the video encoded at different bitrates, including at least the first bitrate and the bitrate that is less than the first bit rate;

determining an available streaming bandwidth;

selecting the file encoded at the first bitrate based on the determined streaming bandwidth,

wherein

the identifying may include receiving level-drop information identifying the replaceable and replacement sections, and

the streaming may include streaming the first sections except for the replaceable sections, and the replacement sections instead of the corresponding replaceable sections based on the identifying information.

The streaming may include receiving requests for the sections of video and transmitting the requested sections of video.

The identifying may include streaming information identifying the replaceable and replacement sections in streaming sources.

In the method, each of the measured levels of objective quality may be based on a signal to noise ratio (SNR) and the predetermined criterion may be based on a one of an absolute SNR level and a relative SNR between the measured levels of objective quality.

A computer program product embodiment corresponding to the above-recited method embodiment comprises a non-transitory computer readable medium encoded with a computer program, including instructions to cause a processor to:

identify

a. replaceable sections among first sections of video encoded at a first bitrate, and

b. replacement sections of the video each encoded at a bitrate that is less than the first bitrate and having encoded therein the video of a corresponding one of the replaceable sections, each replacement section and the corresponding replaceable section having respective measured levels of objective quality that meet a predetermined criterion of objective quality; and

stream the first sections of video except for the replaceable sections, and the replacement sections instead of the corresponding replaceable sections.

The predetermined criterion of objective quality, if met may translate to an acceptable difference in perceptual quality levels of the video decoded from the corresponding replaceable and replacement sections, and then presented.

The replacement sections may include:

first replacement sections encoded at a second bit rate that is less than the first bitrate; and

second replacement sections encoded at a third bitrate that is less than the second bitrate.

The instruction to cause the processor to stream may include instructions to cause the processor to:

stream the first sections except for the replaceable sections from the first file containing the first sections and the replaceable sections; and

stream the replacement sections instead of the replaceable sections from the second file containing the replacement sections.

The instructions may further include instructions to cause the processor to:

request to stream the video;

receive an index to multiple files containing the video encoded at different bitrates, including at least the first bitrate and the bitrate that is less than the first bit rate;

determine an available streaming bandwidth;

select the file encoded at the first bitrate based on the determined streaming bandwidth; and

receive the information identifying the replaceable and replacement sections,

wherein

the instructions to cause the processor to identify may include instructions to cause the processor to receive level-drop information that identifies the replaceable and replacement sections, and

the instructions to cause the processor to stream may include instructions to cause the processor to stream the first sections except for the replaceable sections, and the replacement sections instead of the corresponding replaceable sections, based on the identifying information.

The instructions to cause the processor to stream may include instructions to cause the processor to receive requests for the sections of video and transmit the requested sections of video.

The instructions to cause the processor to identify may include instructions to cause the processor to stream information identifying the replaceable and replacement sections in streaming sources.

Each of the measured levels of objective quality may be based on a signal to noise ratio (SNR) and the predetermined criterion is based on a one of an absolute SNR level and a relative SNR between the measured levels of objective quality.

An apparatus embodiment corresponding to the above method and computer program product embodiments comprises:

a processor and memory configured to:

identify

a. replaceable sections among first sections of video encoded at a first bitrate, and

b. replacement sections of the video each encoded at a bitrate that is less than the first bitrate and having encoded therein the video of a corresponding one of the replaceable sections, each replacement section and the corresponding replaceable section having respective measured levels of objective quality that meet a predetermined criterion of objective quality; and

stream the first sections of video except for the replaceable sections, and the replacement sections instead of the corresponding replaceable sections.

The predetermined criterion of objective quality, if met, may translate to an acceptable difference in perceptual quality levels of the video decoded from the corresponding replaceable and replacement sections, and then presented.

The replacement sections may include:

first replacement sections encoded at a second bit rate that is less than the first bitrate; and

second replacement sections encoded at a third bitrate that is less than the second bitrate.

The processor and memory, configured to stream, may be configured to:

stream the first sections except for the replaceable sections from a first file containing the first sections and the replaceable sections; and

stream the replacement sections instead of the replaceable sections from a second file containing the replacement sections.

The processor and memory may be further configured to:

request to stream the video;

receive an index to multiple files containing the video encoded at different bitrates, including at least the first bitrate and the bitrate that is less than the first bit rate;

determine an available streaming bandwidth;

select the file encoded at the first bitrate based on the determined streaming bandwidth,

wherein

the processor and memory, configured to identify, may be further configured to receive level-drop information identifying the replaceable and replacement sections, and

the processor and memory, configured to stream, may be further configured to stream the first sections except for the replaceable sections, and the replacement sections instead of the corresponding replaceable sections, based on the identifying information.

The processor and memory, configured to stream, may be further configured to receive request for the sections of video and transmit the requested sections of video.

The processor and memory, configured to steam, may be further configured to identify the replaceable and replacement sections from streamed information.

The apparatus may further comprise:

a user interface system;

a communication system to communicate with a network; and

a housing to house the processor and memory, the communication system, and the user interface system.

The communication system may include a wireless communication system; and

the housing includes a mobile hand-held housing to receive the processor and memory, the user interface system, the communication system, and a battery.

While various embodiment are disclosed herein it should be understood that they have been presented by way of example only, and not limitation. It will be apparent to persons skilled in the relevant art that various changes in form and detail may be made therein without departing from the spirit and scope of the methods and systems disclosed herein. Thus, the breadth and scope of the claims should not be limited by any of the examples disclosed herein.

What is claimed is:

1. A method of encoding video, the method performed by an encoding system, comprising:

encoding video at a first bitrate to produce first encoded sections using an encoding system;

encoding the video at a second bitrate that is less than the first bitrate to produce second encoded sections using the encoding system, each having encoded therein the video of a corresponding one of the first encoded sections;

measuring **[**levels of**]** objective quality *levels* using the encoding system, indicative of perceptual quality, of the first and second encoded sections;

determining, based on the measured objective quality levels, *non-replaceable sections among the first encoded sections and* replaceable sections among the first encoded sections, and replacement sections among the second encoded sections using the encoding system, each to replace a corresponding one of the replaceable sections;

generating identifying information that identifies the replaceable sections and their corresponding replacement sections in **[**the**]** *a* first and second container files, respectively, using the encoding system;

constructing a file containing (1) the non-replaceable sections from the first encoded sections and (2) the replacement sections from the second encoded sections;

streaming the identifying information using the encoding system; and

in response to requests from a streaming client device that are dependent on the streamed identifying information, streaming the **[**first encoded**]** *non-replaceable* sections **[**except for the replaceable sections**]** using the encoding device, and streaming the replacement sections instead of their corresponding replaceable sections, **[**at a same time as the corresponding replaceable section would have been streamed had the corresponding replaceable section not been replaced**]** *wherein the streaming includes streaming from the file the non-replaceable sections, and streaming from the file the replacement sections.*

2. The method of claim **1**, wherein the determining includes:

determining, using the encoding device, if corresponding first and second encoded sections have respective measured objective quality levels that each meet a predetermined criterion of objective quality; and

declaring, using the encoding device, the corresponding first and second encoded sections as corresponding replaceable and replacement sections, respectively, if the respective measured objective quality levels each meet the predetermined criterion.

3. The method of claim **2**, wherein the predetermined criterion of objective quality is indicative of an acceptable difference in the perceptual quality levels of the corresponding replaceable and replacement sections when decoded and presented.

4. The method of claim **2**, wherein the predetermined criterion of objective quality is one of:

a threshold level of objective quality that must be exceeded by each of the respective measured objective quality levels; and

a maximum difference between the respective measured objective quality levels that must not be exceeded.

5. The method of claim **1**, wherein:

the measuring includes measuring a signal-to-noise ratio (SNR) as the objective quality level; and

the determining includes determining whether the measured objective quality levels meet a predetermined criterion that is based on one of an absolute objective quality level and a relative objective quality level.

[**6**. The method of claim **1**, further comprising:

constructing a first file containing the first encoded sections, including the replaceable sections;

constructing a second file containing the second encoded sections, including the replacement sections; and

wherein the streaming includes:

streaming the first encoded sections, except for the replaceable sections, from the first container file; and

streaming the replacement sections from the second container file.]

[**7**. The method of claim **1**, further comprising constructing a file containing the first encoded sections, except for the replaceable sections which are replaced by their corresponding replacement sections, wherein the streaming includes streaming from the file the first encoded sections, except for the replaceable sections, and the replacement sections.]

8. A non-transitory computer readable medium encoded with a computer program, including instructions to cause a processor to:

encode video at a first bitrate to produce first encoded sections;

encode the video at a second bitrate that is less than the first bitrate to produce second encoded sections, each having encoded therein the video of a corresponding one of the first encoded sections;

measure objective quality levels, indicative of perceptual quality levels, of the first and second encoded sections;

determine, based on the measured objective quality levels, *non-replaceable sections among the first encoded sections and* replaceable sections among the first encoded sections, and replacement sections among the second encoded sections, each to replace a corresponding one of the replaceable sections;

generate identifying information that identifies the replaceable sections and their corresponding replacement sections in [the] *a* first and second container files, respectively, using the encoding system;

constructing a file containing (1) the non-replaceable sections from the first encoded sections and (2) the replacement sections from the second encoded sections;

stream the identifying information; and

in response to requests from a playback device that are dependent on the streamed identifying information, stream the [first encoded] *non-replaceable* sections [except for the replaceable sections,] and stream the replacement sections instead of their corresponding replaceable sections, [at a same time as the corresponding replaceable section would have been streamed had the corresponding replaceable section not been replaced] *wherein the streaming includes streaming from the file the non-replaceable sections, and streaming from the file the replacement sections*.

9. The computer readable medium of claim **8**, wherein the instructions to cause the processor to determine include instructions to cause the processor to:

determine if corresponding first and second encoded sections have respective measured objective quality levels that each meet a predetermined criterion of objective quality; and

declare the corresponding first and second encoded sections as corresponding replaceable and replacement sections, respectively, if the respective measured objective quality levels each meet the predetermined criterion.

10. The computer readable medium of claim **9**, wherein the predetermined criterion of objective quality is indicative of an acceptable difference in the perceptual quality levels of the corresponding replaceable and replacement sections when decoded and presented.

11. The computer readable medium of claim **9**, wherein the predetermined criterion of objective quality is one of:

a threshold level of objective quality that must be exceeded by each of the respective measured objective quality levels; and

a maximum difference between the respective measured objective quality levels that must not be exceeded.

12. The computer readable medium of claim **8**, wherein:

the instructions to cause the processor to measure include instructions to cause the processor to measure a signal-to-noise ratio (SNR) as the objective quality level; and

the instructions to cause the processor to determine include instructions to cause the processor to determine whether the measured objective quality levels meet a predetermined criterion that is based on one of an absolute objective quality level and a relative objective quality level.

[**13**. The computer readable medium of claim **8**, wherein the instructions further include instructions to cause the processor to:

construct a first file containing the first encoded sections, including the replaceable sections;

construct a second file containing the second encoded sections, including the replacement sections; and

wherein the instructions to cause the processor to stream include instructions to cause the processor to:

stream the first encoded sections, except for the replaceable sections, from the first container file; and

stream the replacement sections from the second container file.]

[**14**. The computer readable medium of claim **8**, further comprising constructing a file containing the first encoded sections, except for the replaceable sections which are replaced by their corresponding replacement sections, wherein the streaming includes streaming from the file the first encoded sections, except for the replaceable sections, and the replacement sections.]

15. An *encoding* apparatus, comprising:

a processor*;*

[and] *a* memory [configured to] *storing computer executable instructions which when executed cause the processor to*:

encode video at a first bitrate to produce first encoded sections, and encode the video at a second bitrate that is less than the first bitrate to produce second encoded sections, each having encoded therein the video of a corresponding one of the first encoded sections;

measure objective quality levels, indicative of perceptual quality levels, of the first and second encoded sections;

determine, based on the measured objective quality levels, non-replaceable sections among the first encoded sections and replaceable sections among the first encoded sections, and replacement sections among the second encoded sections, each to replace a corresponding one of the replaceable sections; and

generate identifying information that identifies the replaceable sections and their corresponding replacement sections in [the] *a* first and second container files, respectively, using the encoding system;

construct a file containing (1) the non-replaceable sections from the first encoded sections and (2) the replacement sections rom the second encoded sections;

stream the identifying information; and

in response to requests from a playback device that are dependent on the streamed identifying information, stream the [first encoded] *non-replaceable* sections [except for the replaceable sections,] and the replacement sections instead of their corresponding replaceable sections, [at a same time as the corresponding replaceable section would have been streamed had the corresponding replaceable section not been replaced] *wherein the streaming includes streaming from the file the non-replaceable sections, and streaming from the file the replacement sections*.

16. The *encoding* apparatus of claim 15, wherein the [processor and memory, configured to determine, are further configured] *processor when executing the instructions in the memory is further configured to:* determine if corresponding first and second encoded sections have respective measured objective quality levels that each meet a predetermined criterion of objective quality; and declare the corresponding first and second encoded sections as corresponding replaceable and replacement sections, respectively, if the respective measured objective quality levels each meet the predetermined criterion.

17. The *encoding* apparatus of claim 16, wherein the predetermined criterion of objective quality is indicative of an acceptable difference in the perceptual quality levels of the corresponding replaceable and replacement sections when decoded and presented.

18. The *encoding* apparatus of claim 16, wherein the predetermined criterion of objective quality is one of: a threshold level of objective quality that must be exceeded by each of the respective measured objective quality levels; and a maximum difference between the respective measured objective quality levels that must not be exceeded.

19. The *encoding* apparatus of claim 16, wherein [the processor and memory, configured to measure, are further configured] *the processor when executing the instructions in the memory is further configured* to measure a signal-to-noise ratio (SNR) as the objective quality level; and the processor and memory, configured to determine, are further configured to determine whether the measured objective quality levels meet a predetermined criterion that is based on one of an absolute objective quality level and a relative objective quality level.

[20. The apparatus of claim 16, wherein:

the processor and memory are further configured to

construct a first file containing the first encoded sections, including the replaceable sections, and

construct a second file containing the second encoded sections, including the replacement sections; and

the processor and memory, configured to stream, are further configured to

stream the first encoded sections, except for the replaceable sections, from the first container file, and

stream the replacement sections from the second container file.]

[21. The apparatus of claim 16, wherein:

the processor and memory are further configured to construct a file containing the first encoded sections, except for the replaceable sections which are replaced by their corresponding replacement sections; and

the processor and memory, configured to stream, are further configured to stream from the file the first encoded sections, except for the replaceable sections, and the replacement sections.]

22. The *encoding* apparatus of claim 15, further comprising: a communication system to communicate with a network; and a housing to house the processor and memory, and the communication system.

23. A content distribution system, comprising:

a set of one or more encoding servers, wherein each server of the set of encoding servers comprises:

a non-volatile storage storing computer executable instructions; and

at least one processor;

wherein the computer executable instructions, which when executed cause the processors in the set of one or more encoding servers to encode source content by:

encoding a portion of video at a first bitrate to produce a first encoded section;

encoding the same portion of video at a second bitrate that is less than the first bitrate to produce a second encoded section;

measuring objective quality levels with respect to each of the first and second encoded sections;

selecting one of the first and second encoded sections based on the measured objective quality levels of the first and second encoded sections;

constructing a file containing the selected one of the first and second encoded sections, wherein the file contains at least one encoded section encoded at the first bitrate and at least one encoded section encoded at the second bitrate;

storing a video stream comprising the file containing the selected one of the first and second encoded sections; and

streaming the stored video stream in response to a request from a playback device.

24. The content distribution system of claim 23, wherein the first and second sections encode video at a same resolution.

25. The content distribution system of claim 23, wherein the first and second encoded sections are each a self-contained unit of media capable of being decoded without reference to any other encoded section.

26. The content distribution system of claim 25, wherein the video stream comprises a plurality of encoded sections including the selected one of the first and second encoded sections and each of the plurality of encoded sections encodes a fixed duration of media.

27. The content distribution system of claim 25, wherein the video stream comprises a plurality of encoded sections including the selected one of the first and second encoded sections and at least some of the plurality of encoded sections encode different durations of media.

28. The content distribution system of claim 23, wherein each of the first and second encoded sections comprises a number of successive frames of video.

29. The content distribution system of claim 23, wherein a measured objective quality of a section of video is at least one measure selected from the group consisting of: a signal-to-noise ratio (SNR) of the section, a peak SNR (PSNR) of the section, and a structural similarity index (SSIM) that measures a similarity between sections.

30. The content distribution system of claim 23, wherein the processor when executing the instructions in the memory is further configured to encode source content by:

determining when the second encoded section has a respective measured objective quality level that meets a predetermined criterion for objective quality; and

selecting the corresponding second encoded section when the measured objective quality level meets the predetermined criterion.

31. The content distribution system of claim 30, wherein the predetermined criterion of objective quality is indicative of an acceptable difference in the perceptual quality levels of the corresponding first and second sections when decoded and presented.

32. The content distribution system of claim 30, wherein the measuring includes measuring a signal-to-noise ratio (SNR) as the objective quality level; and the determining includes determining whether the measured objective quality level meet a predetermined criterion that is based on one of an absolute objective quality level and a relative objective quality level.

33. A content distribution system, comprising:

a set of one or more encoding servers, wherein each server of the set of encoding servers comprises:

a non-volatile storage storing computer executable instructions; and

at least one processor;

wherein the computer executable instructions, which when executed, cause the processor to encode source content by:

encoding a portion of video at a first bitrate to produce a first encoded section, where the first encoded section is a self-contained unit of media capable of being decoded without reference to any other encoded section;

encoding the same portion of video at a second bitrate that is less than the first bitrate to produce a second encoded section, where the second encoded section is a self-contained unit of media capable of being decoded without reference to any other encoded section;

measuring objective quality levels with respect to each of the first and second encoded sections;

determining when the second encoded section has a respective measured objective quality level that meets a predetermined criterion for objective quality;

selecting one of the first and second encoded sections based on the measured objective quality levels of the first and second encoded sections, where the second encoded section is selected when the measured objective quality level of the second encoded section meets the predetermined criterion for objective quality; and;

constructing a file containing the selected one of the first and second encoded sections, wherein the file contains at least one encoded section encoded at the first bitrate and at least one encoded section encoded at the second bitrate;

storing a video stream comprising the file containing the selected one of the first and second encoded sections;

streaming the stored video stream in response to a request from a playback device.

* * * * *