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(54) **PLAYBACK DEVICES AND METHODS FOR PLAYING BACK ALTERNATIVE STREAMS OF CONTENT PROTECTED USING A COMMON SET OF CRYPTOGRAPHIC KEYS**

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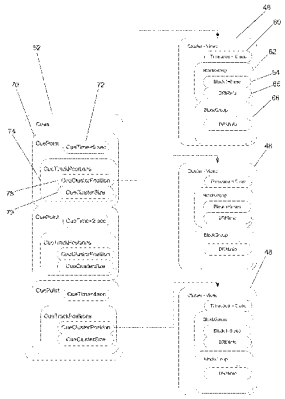
(57) **ABSTRACT**

Systems and methods for performing adaptive bitrate streaming using alternative streams of protected content in accordance with embodiments of the invention are described. One embodiment of the invention includes a processor, and memory containing a client application. In addition, the client application configures the processor to: request a top level index file identifying a plurality of alternative streams of protected content, where each of the alternative streams of protected content are encrypted using common cryptographic information; obtain the common cryptographic information; request portions of content from at least the plurality of alternative streams of protected content; access the protected content using the common cryptographic information; and playback the content.

24 Claims, 19 Drawing Sheets



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See application file for complete search history.

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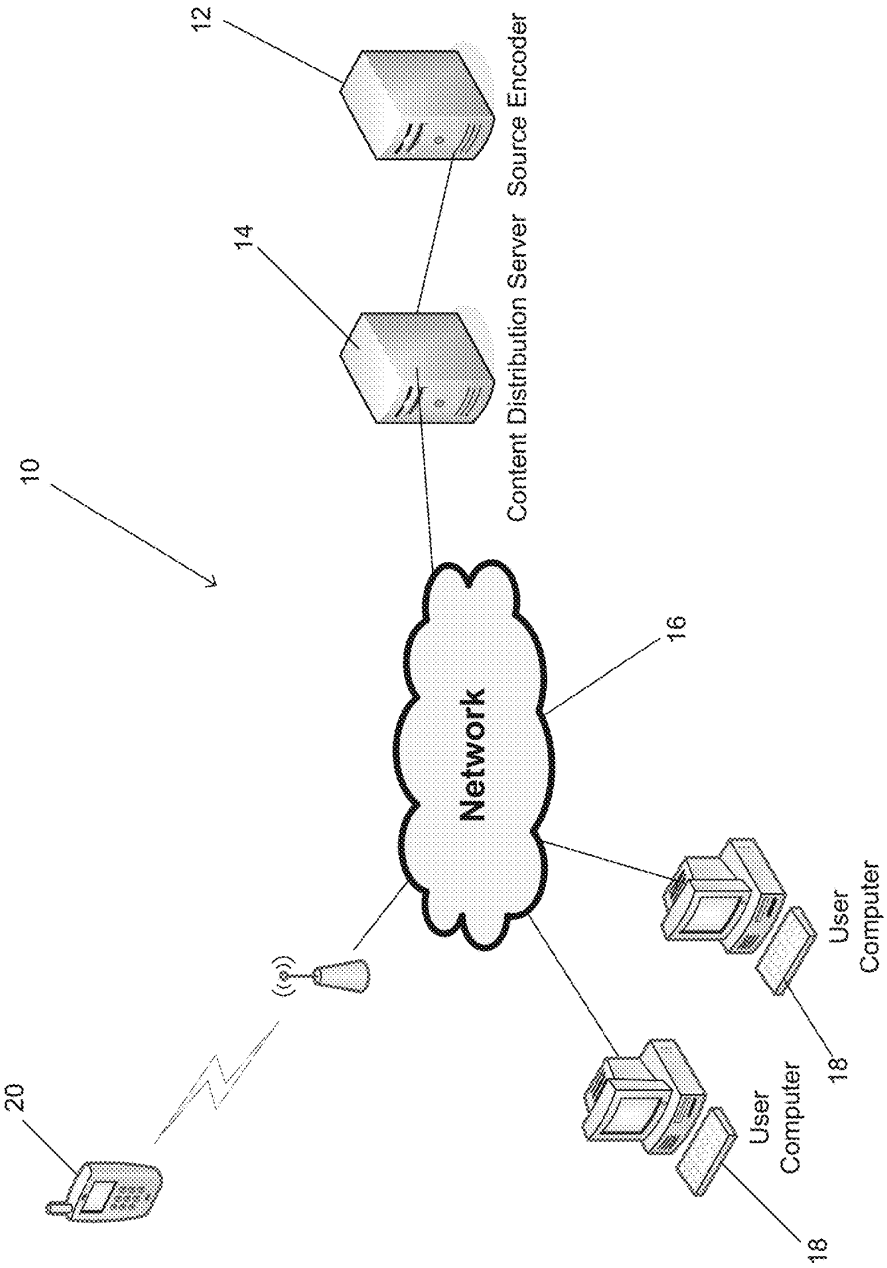
10
12
Source Encoder
14
Content Distribution Server
Network
16
User Computer
18
User Computer
18
20

FIG. 1A

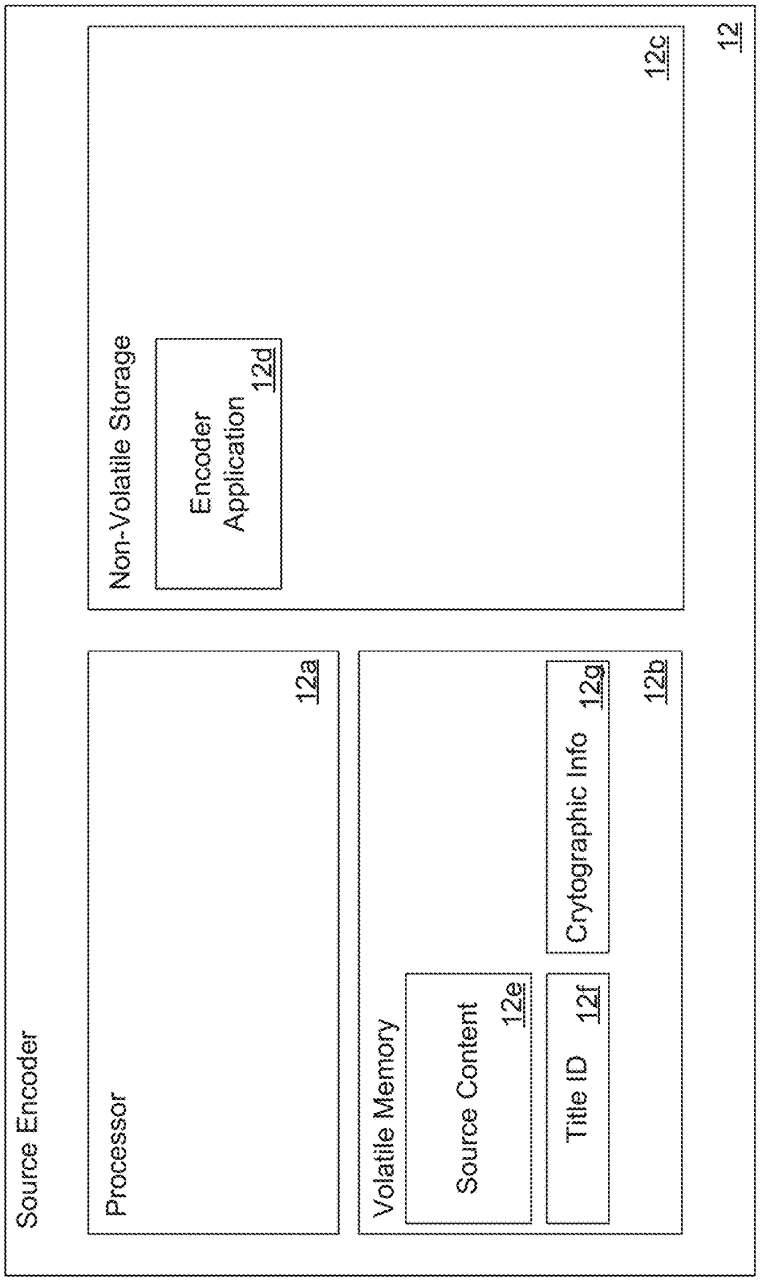
Source Encoder
Processor
12a
Volatile Memory
Source Content
12e
Title ID
12f
Crytographic Info
12g
12b
Non-Volatile Storage
Encoder Application
12d
12c
12

FIG. 1B

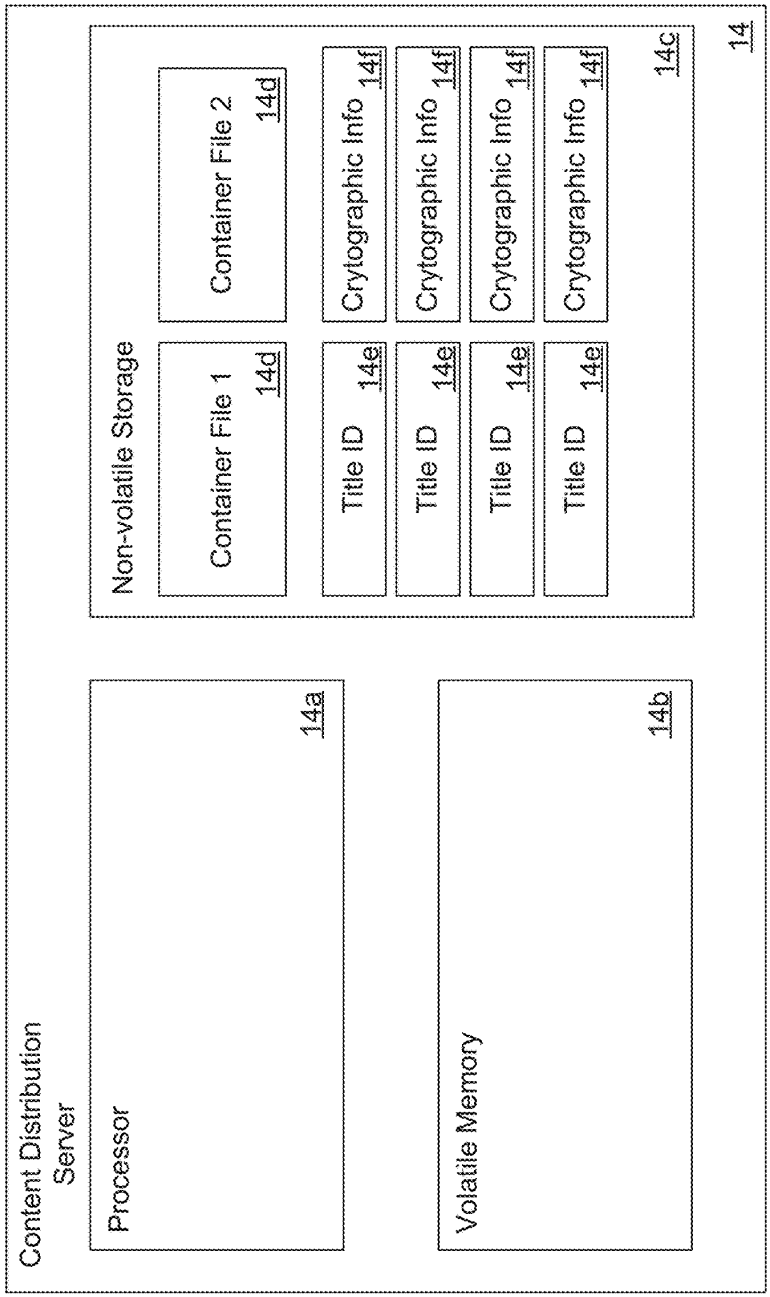
Content Distribution Server
14
Processor
14a
Volatile Memory
14b
Non-volatile Storage
14c
Container File 1
14d
Container File 2
14d
Title ID
14e
Title ID
14e
Title ID
14e
Title ID
14e
Crytographic Info
14f
Crytographic Info
14f
Crytographic Info
14f
Crytographic Info
14f

FIG. 1C

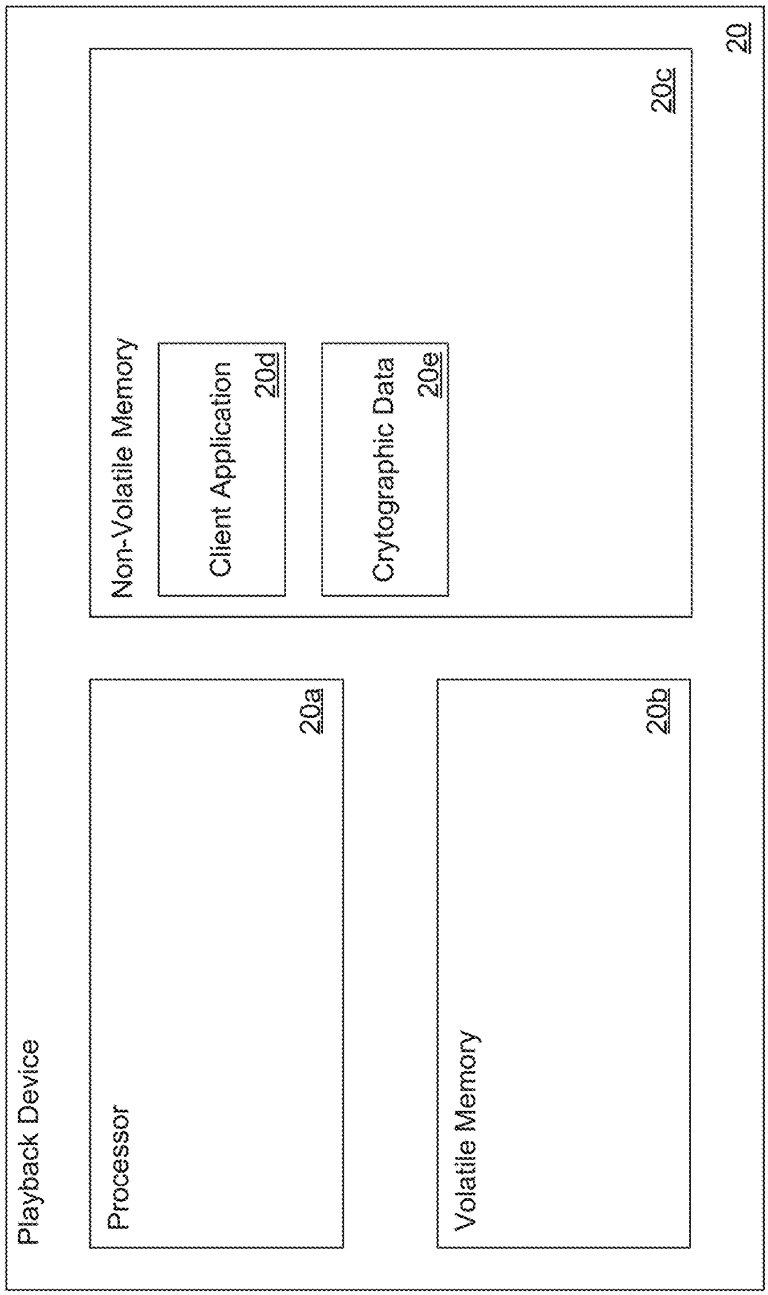
Playback Device
Processor
20a
Volatile Memory
20b
Non-Volatile Memory
Client Application
20d
Crytographic Data
20e
20c
20

FIG. 1D

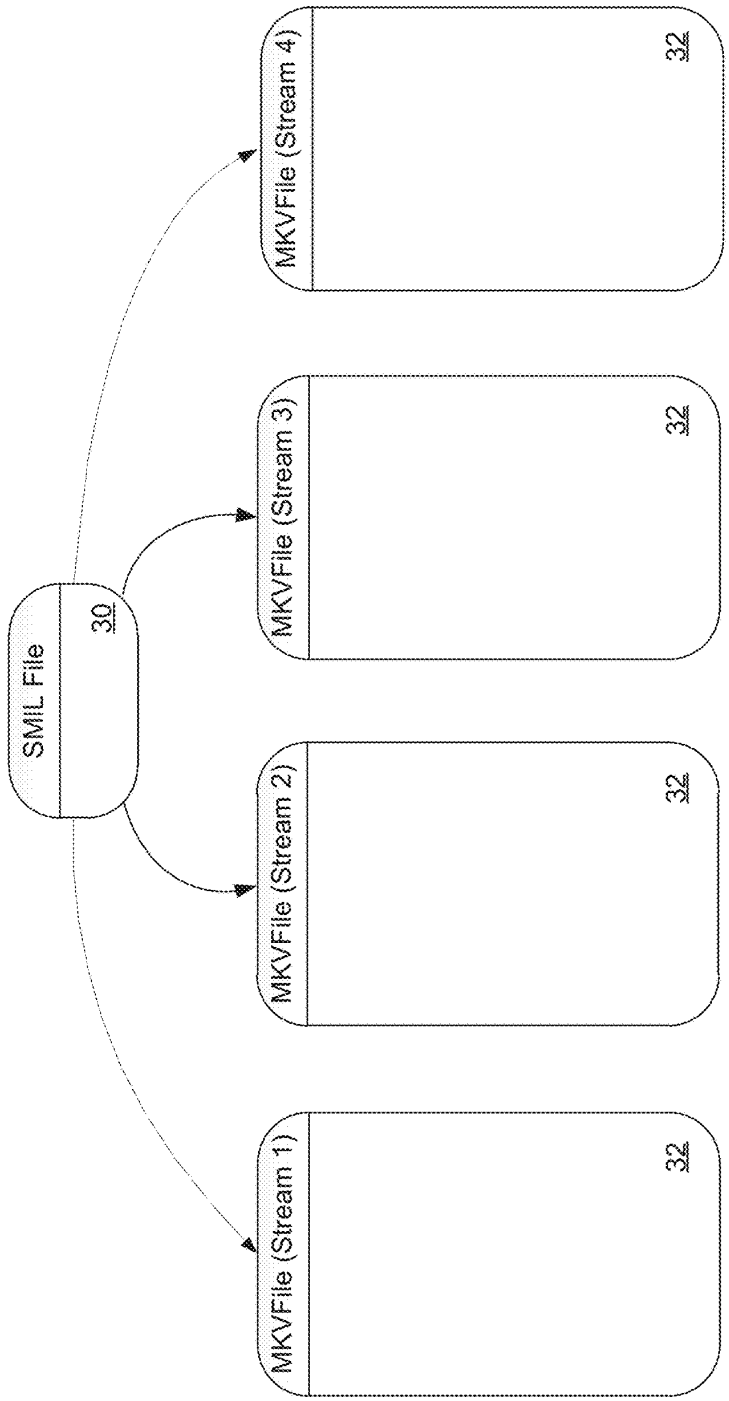
SMIL File
30
MKVFile (Stream 1)
32
MKVFile (Stream 2)
32
MKVFile (Stream 3)
32
MKVFile (Stream 4)
32

FIG. 2

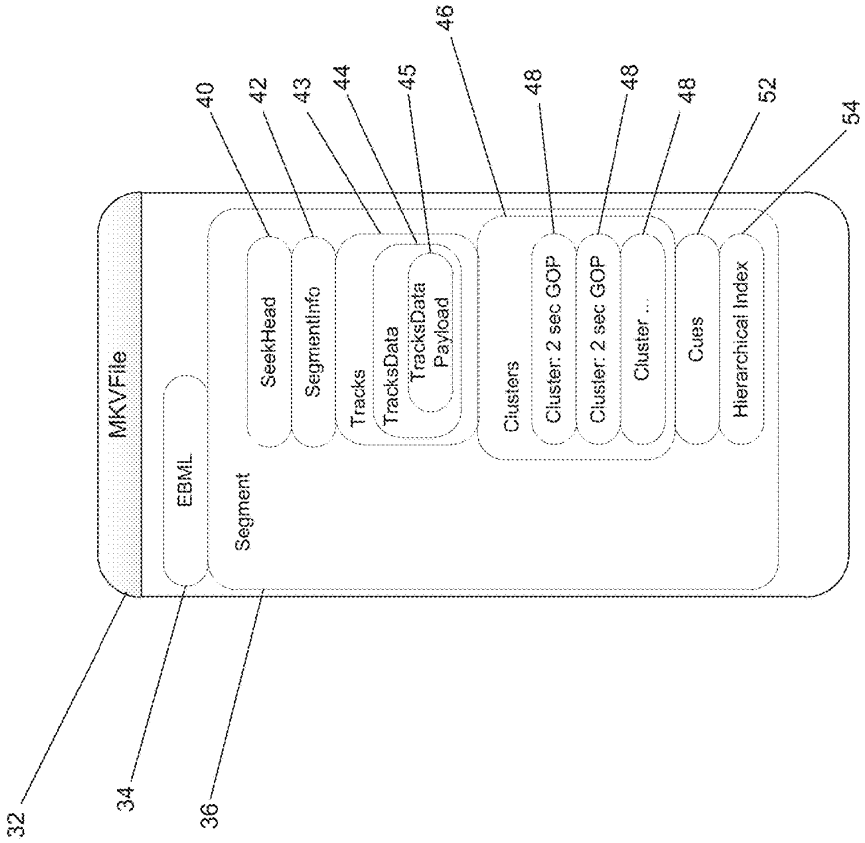
MKVFile
EBML
Segment
SeekHead
SegmentInfo
Tracks
TracksData
TracksData Payload
Clusters
Cluster: 2 sec GOP
Cluster: 2 sec GOP
Cluster ...
Cues
Hierarchical Index
32
34
36
40
42
43
44
45
46
48
48
48
52
54

FIG. 3

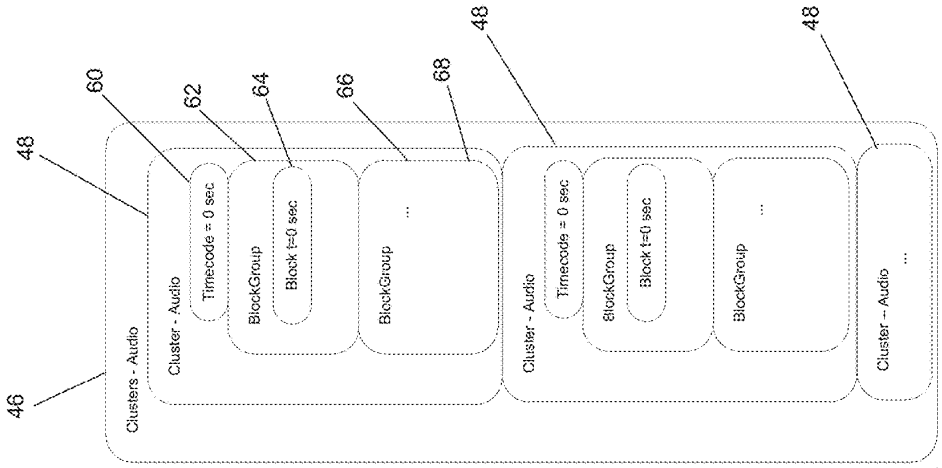
46
48
60
62
64
66
68
48
48
Clusters - Audio
Cluster - Audio
Timecode = 0 sec
BlockGroup
Block t=0 sec
BlockGroup
...
Cluster - Audio
Timecode = 0 sec
BlockGroup
Block t=0 sec
BlockGroup
...
Cluster – Audio
...

FIG. 4b

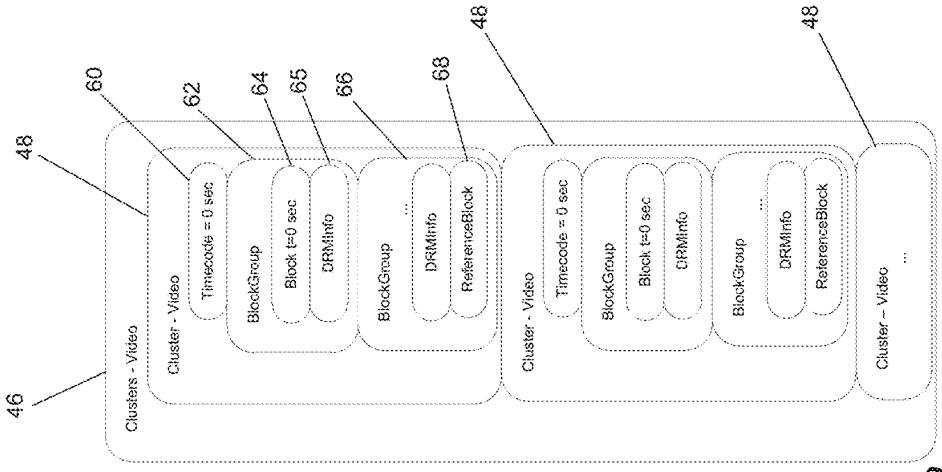
46
48
60
62
64
65
66
68
48
48
Clusters - Video
Cluster - Video
Timecode = 0 sec
BlockGroup
Block t=0 sec
DRMInfo
BlockGroup
...
DRMInfo
ReferenceBlock
Cluster - Video
Timecode = 0 sec
BlockGroup
Block t=0 sec
DRMInfo
BlockGroup
...
DRMInfo
ReferenceBlock
Cluster – Video
...

FIG. 4a

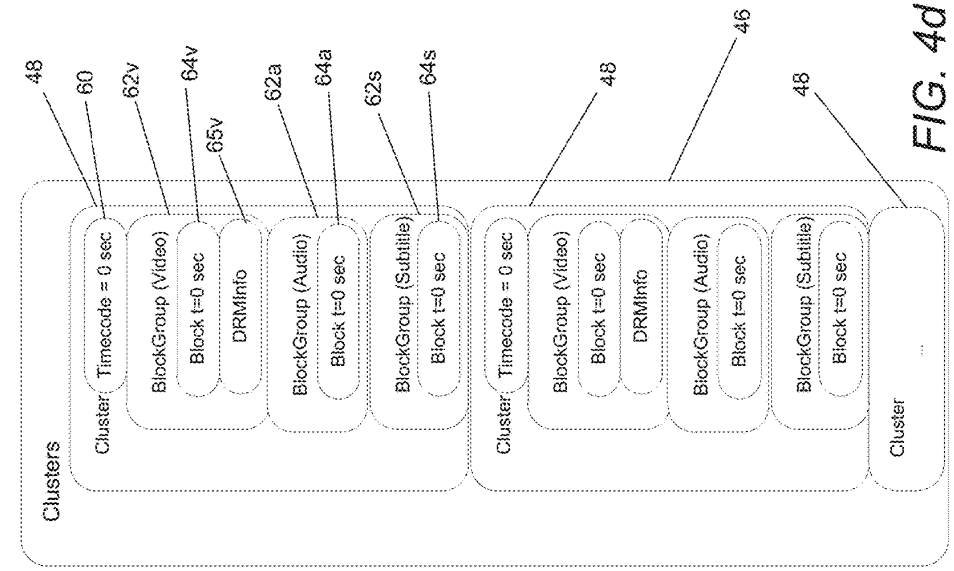
Clusters
Cluster
Timecode = 0 sec
BlockGroup (Video)
Block t=0 sec
DRMInfo
BlockGroup (Audio)
Block t=0 sec
BlockGroup (Subtitle)
Block t=0 sec
Cluster
Timecode = 0 sec
BlockGroup (Video)
Block t=0 sec
DRMInfo
BlockGroup (Audio)
Block t=0 sec
BlockGroup (Subtitle)
Block t=0 sec
Cluster
...
48
60
62v
64v
65v
62a
64a
62s
64s
48
46
48

FIG. 4d

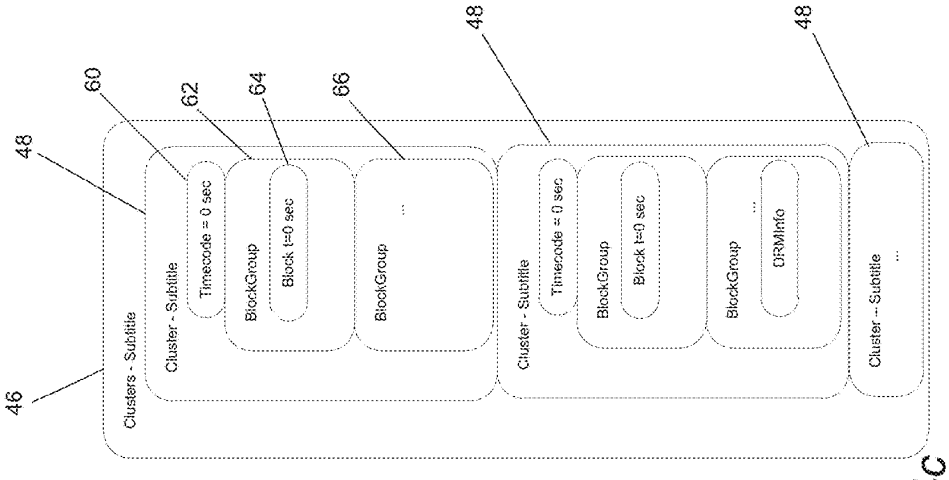
Clusters - Subtitle
Cluster - Subtitle
Timecode = 0 sec
BlockGroup
Block t=0 sec
BlockGroup
...
Cluster - Subtitle
Timecode = 0 sec
BlockGroup
Block t=0 sec
BlockGroup
...
DRMInfo
Cluster -- Subtitle
...
46
48
60
62
64
66
48
48

FIG. 4c

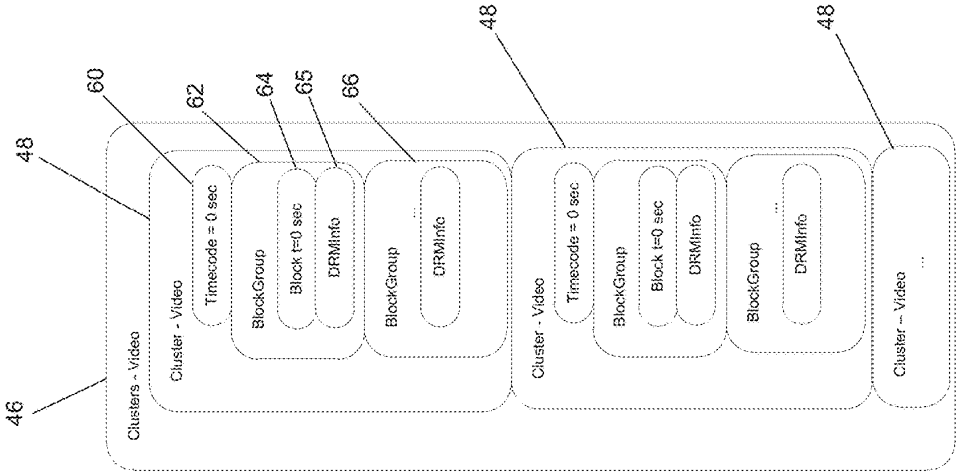
46
48
Clusters - Video
60
Cluster - Video
Timecode = 0 sec
62
BlockGroup
64
Block t=0 sec
65
DRMInfo
66
BlockGroup
DRMInfo
48
Cluster - Video
Timecode = 0 sec
BlockGroup
Block t=0 sec
DRMInfo
BlockGroup
...
DRMInfo
48
Cluster - Video
...

FIG. 4e

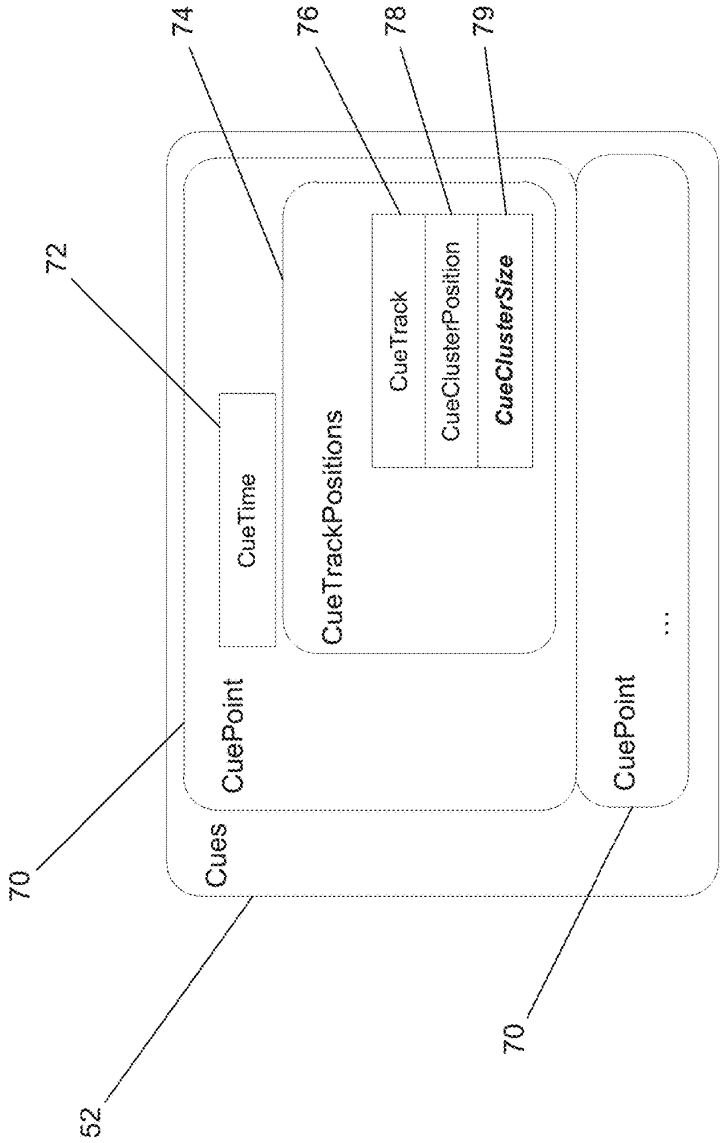
74
76
78
79
72
CueTime
CueTrack
CueClusterPosition
CueClusterSize
CueTrackPositions
CuePoint
...
CuePoint
Cues
70
52
70

FIG. 5

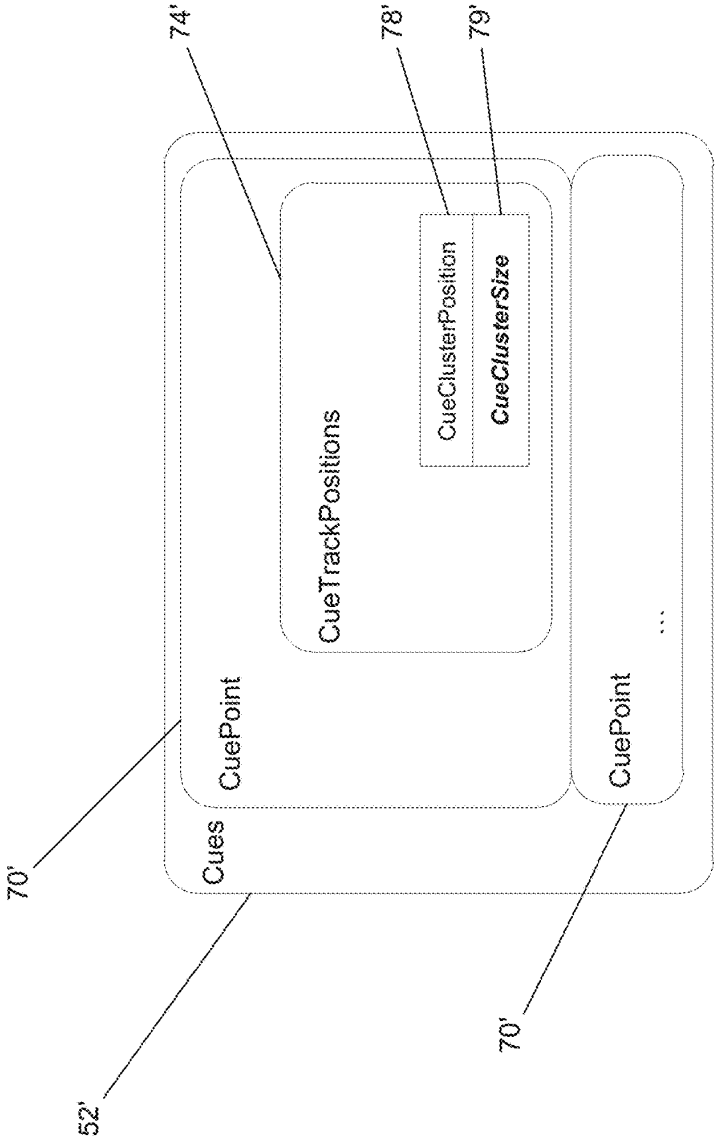
74'
78'
79'
CueClusterPosition
CueClusterSize
CueTrackPositions
CuePoint
Cues
CuePoint
...
70'
52'
70'

FIG. 5a

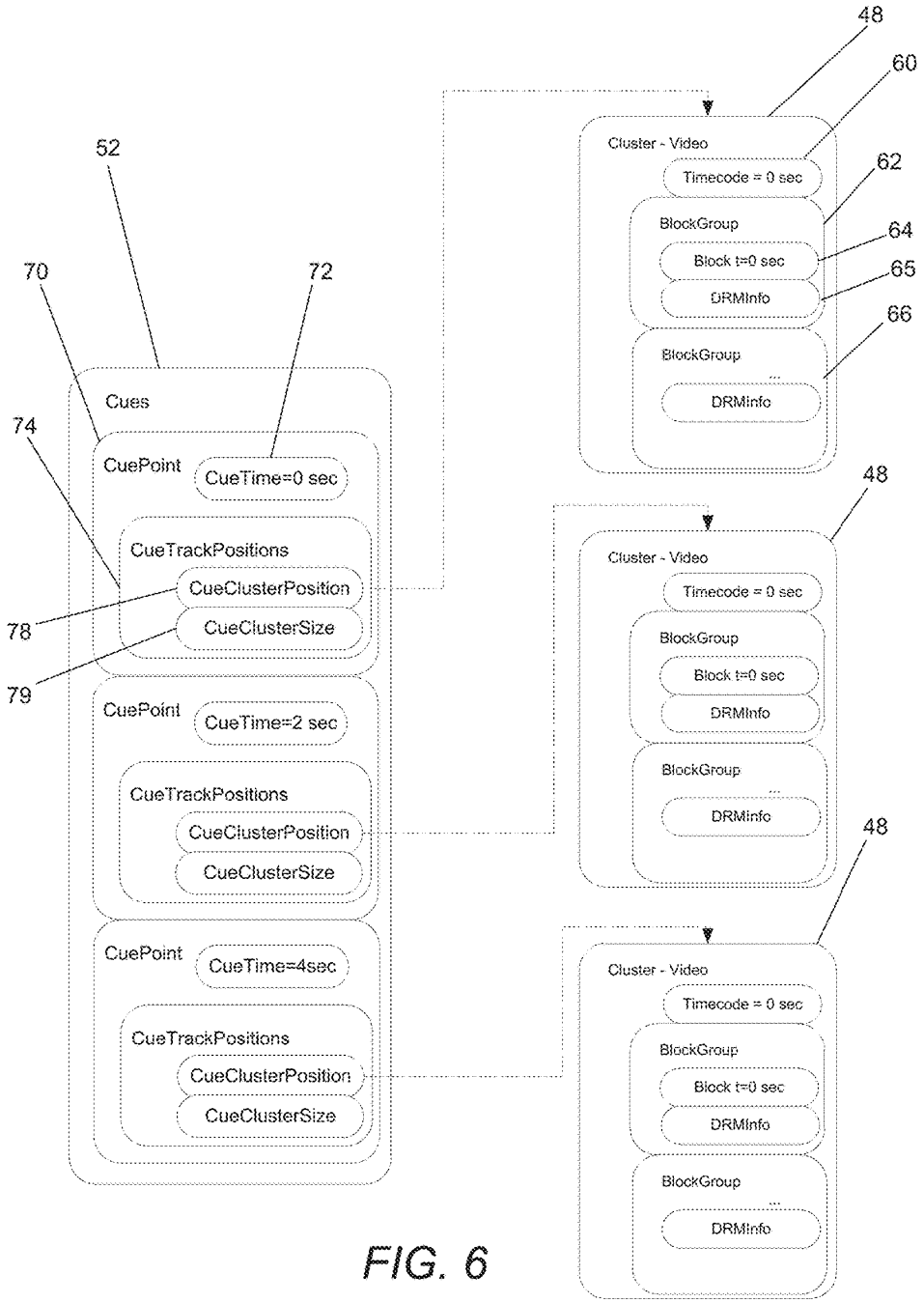
48
60
52
Cluster - Video
Timecode = 0 sec
62
BlockGroup
64
Block t=0 sec
65
DRMInfo
66
70
72
BlockGroup
...
DRMInfo
Cues
74
CuePoint
CueTime=0 sec
48
CueTrackPositions
Cluster - Video
CueClusterPosition
Timecode = 0 sec
78
CueClusterSize
BlockGroup
79
Block t=0 sec
DRMInfo
CuePoint
CueTime=2 sec
BlockGroup
...
CueTrackPositions
DRMInfo
CueClusterPosition
48
CueClusterSize
CuePoint
CueTime=4sec
Cluster - Video
Timecode = 0 sec
CueTrackPositions
BlockGroup
CueClusterPosition
Block t=0 sec
CueClusterSize
DRMInfo
BlockGroup
...
DRMInfo

FIG. 6

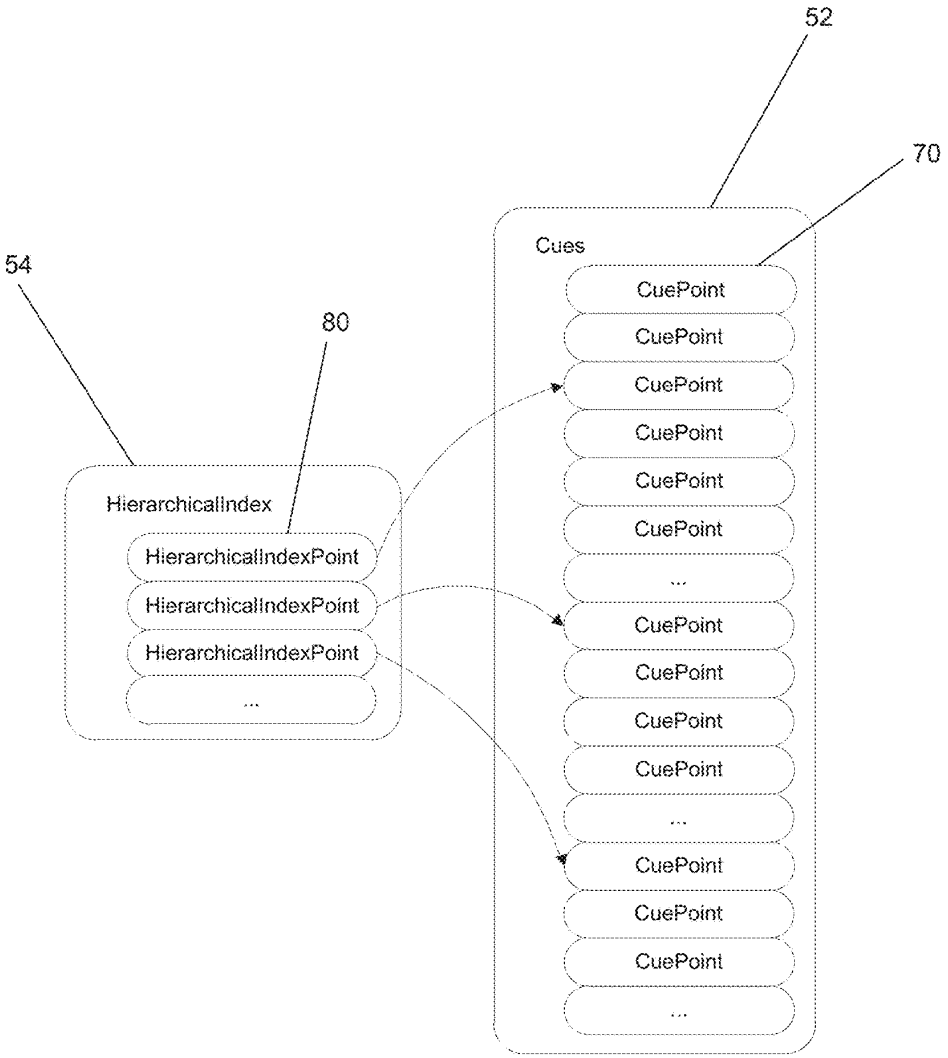
52
70
54
80
Cues
CuePoint
CuePoint
CuePoint
CuePoint
CuePoint
CuePoint
...
CuePoint
CuePoint
CuePoint
CuePoint
...
CuePoint
CuePoint
CuePoint
...
HierarchicalIndex
HierarchicalIndexPoint
HierarchicalIndexPoint
HierarchicalIndexPoint
...

FIG. 7

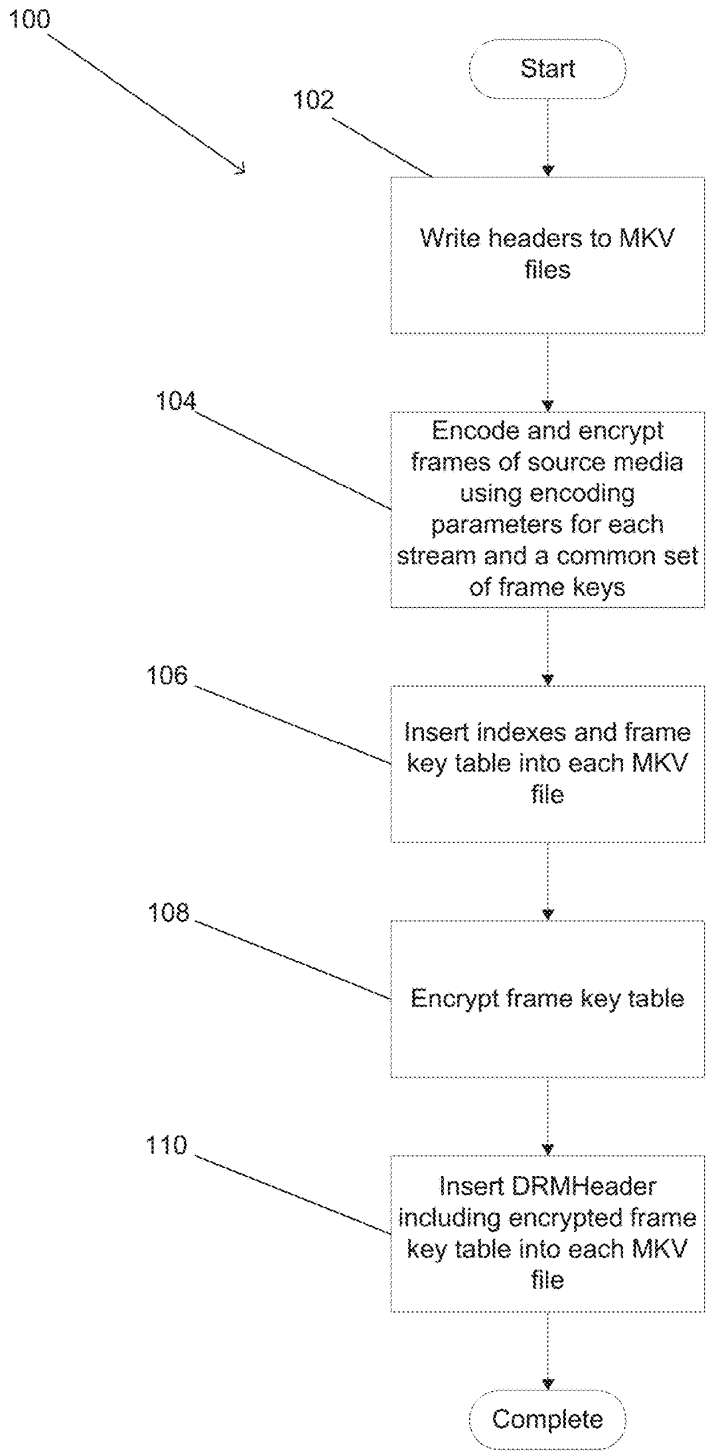
100
Start
102
Write headers to MKV files
104
Encode and encrypt frames of source media using encoding parameters for each stream and a common set of frame keys
106
Insert indexes and frame key table into each MKV file
108
Encrypt frame key table
110
Insert DRMHeader including encrypted frame key table into each MKV file
Complete

FIG. 8

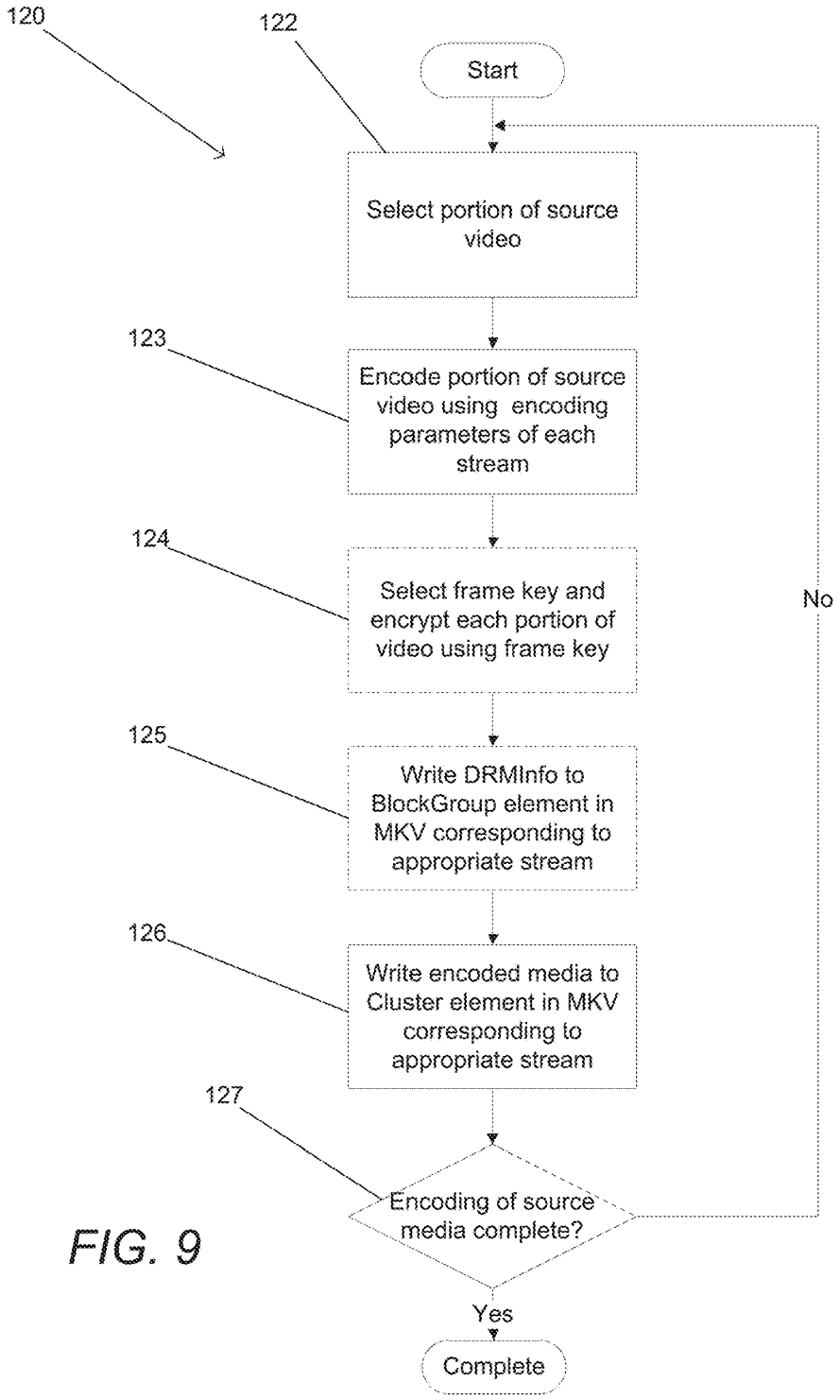
120
122
Start
Select portion of source video
123
Encode portion of source video using encoding parameters of each stream
124
Select frame key and encrypt each portion of video using frame key
125
Write DRMInfo to BlockGroup element in MKV corresponding to appropriate stream
126
Write encoded media to Cluster element in MKV corresponding to appropriate stream
127
Encoding of source media complete?
No
Yes
Complete

FIG. 9

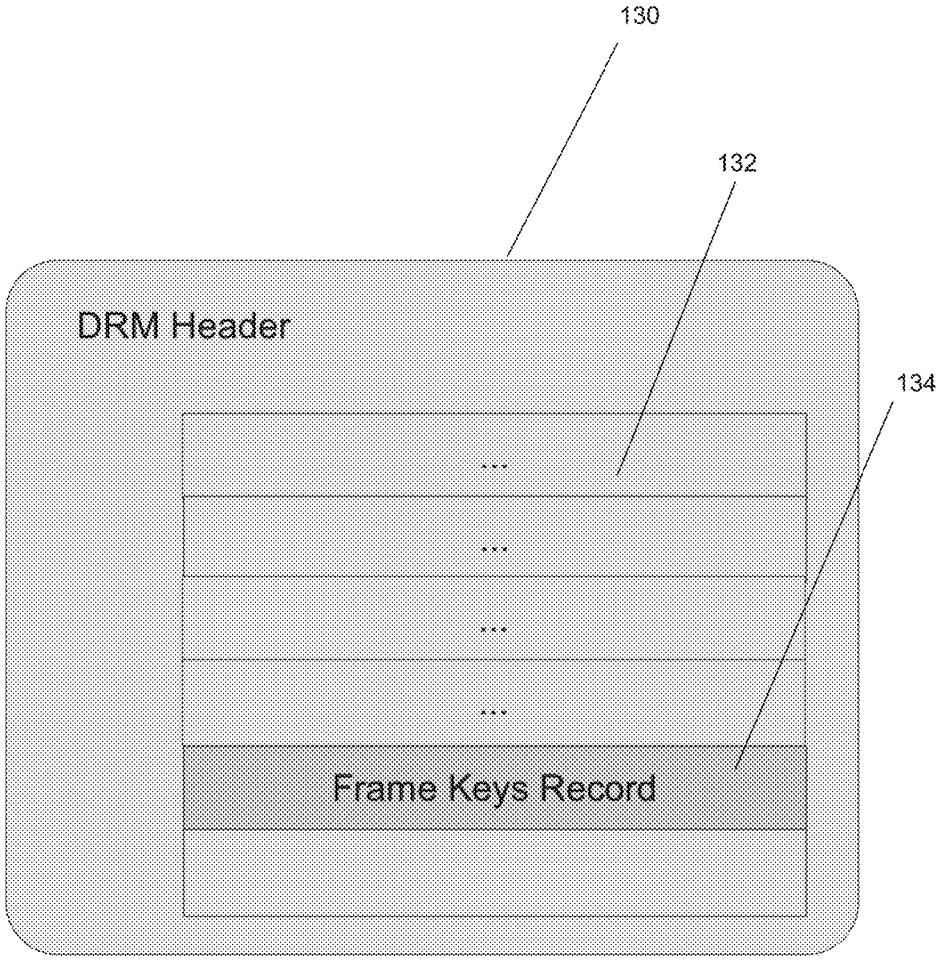

FIG. 10

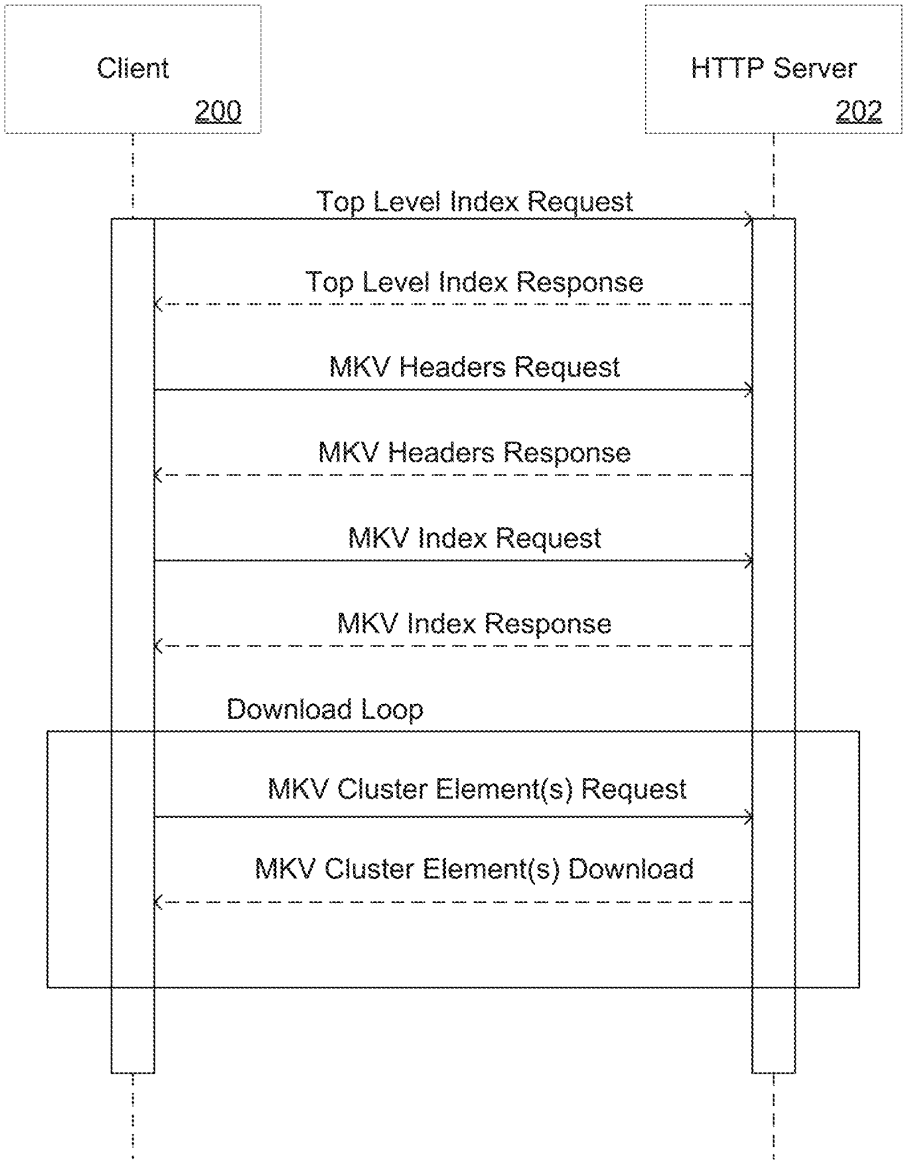
Client
200
HTTP Server
202
Top Level Index Request
Top Level Index Response
MKV Headers Request
MKV Headers Response
MKV Index Request
MKV Index Response
Download Loop
MKV Cluster Element(s) Request
MKV Cluster Element(s) Download

FIG. 11

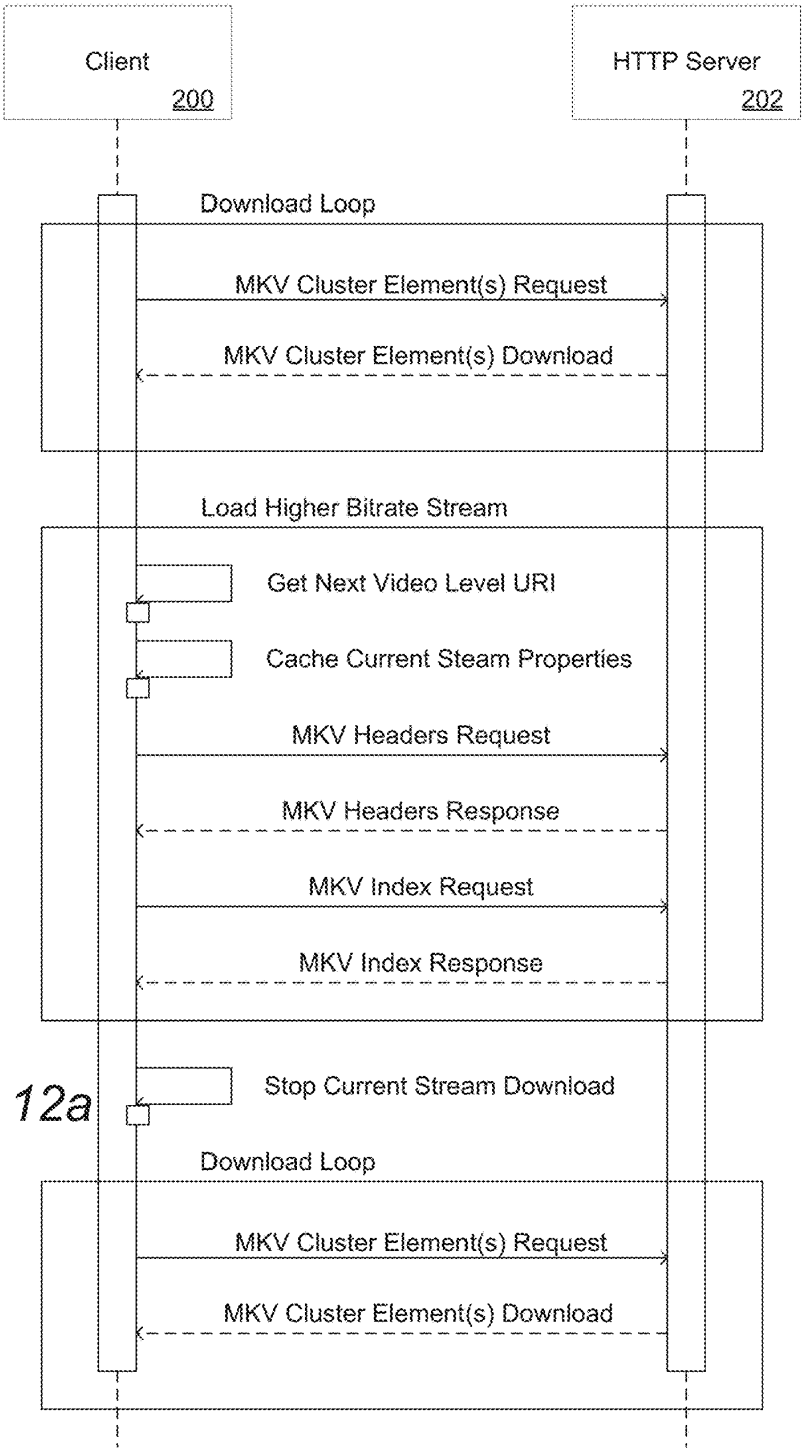
Client
200
HTTP Server
202
Download Loop
MKV Cluster Element(s) Request
MKV Cluster Element(s) Download
Load Higher Bitrate Stream
Get Next Video Level URI
Cache Current Steam Properties
MKV Headers Request
MKV Headers Response
MKV Index Request
MKV Index Response
Stop Current Stream Download
Download Loop
MKV Cluster Element(s) Request
MKV Cluster Element(s) Download

FIG. 12a

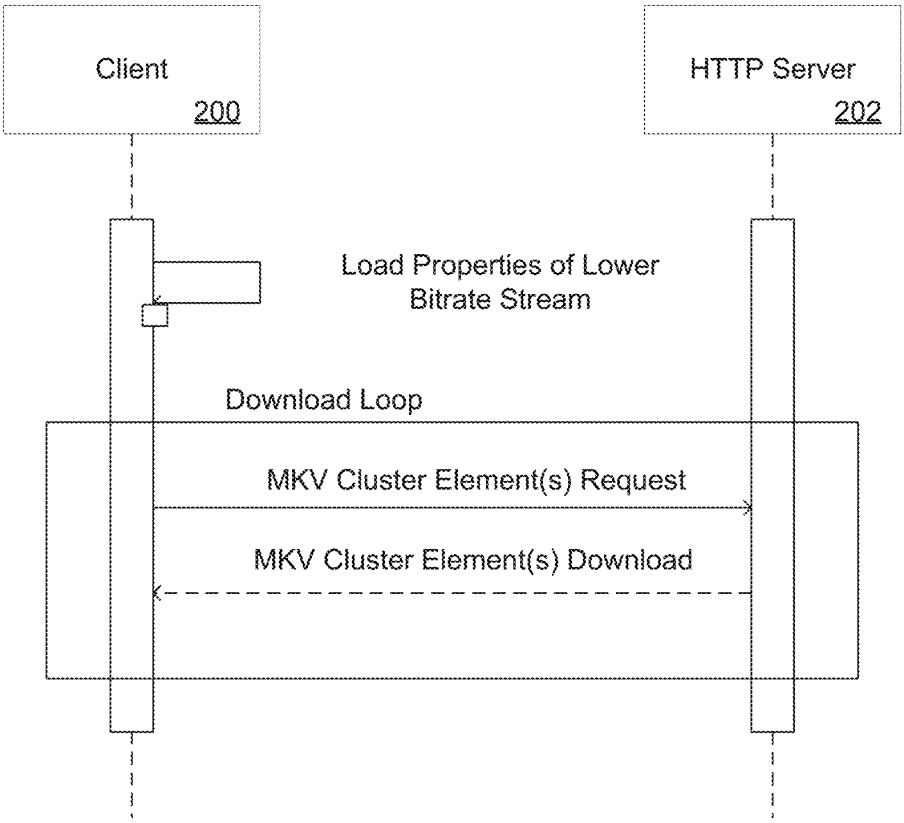
Client
200
HTTP Server
202
Load Properties of Lower Bitrate Stream
Download Loop
MKV Cluster Element(s) Request
MKV Cluster Element(s) Download

FIG. 12b

PLAYBACK DEVICES AND METHODS FOR PLAYING BACK ALTERNATIVE STREAMS OF CONTENT PROTECTED USING A COMMON SET OF CRYPTOGRAPHIC KEYS

CROSS REFERENCE TO RELATED APPLICATIONS

The current application is a continuation of U.S. patent application Ser. No. 15/481,340, filed Apr. 6, 2017, entitled "Systems and Methods for Playing Back Alternative Streams of Protected Content Protected Using Common Cryptographic Information" to Kiefer et al., which application is a continuation of U.S. patent application Ser. No. 14/970,412, filed Dec. 15, 2015, entitled "Systems and Methods for Playing Back Alternative Streams of Protected Content Protected Using Common Cryptographic Information" to Kiefer et al., which is a continuation of U.S. patent application Ser. No. 14/564,003, filed Dec. 8, 2014 and issued on Jan. 26, 2016 as U.S. Pat. No. 9,247,311, entitled "Systems and Methods for Playing Back Alternative Streams of Protected Content Protected Using Common Cryptographic Information" to Kiefer et al., which application is a continuation of U.S. patent application Ser. No. 13/340,623, filed Dec. 29, 2011 and issued on Dec. 9, 2014 as U.S. Pat. No. 8,909,922, entitled "Systems and Methods for Playing Back Alternative Streams of Protected Content Protected Using Common Cryptographic Information" to Kiefer et al., which application claims priority under 35 U.S.C. § 119(e) to U.S. Provisional Application Ser. No. 61/530,305 filed Sep. 1, 2011, entitled "Multi-Asset Protected Content Multimedia Delivery System", the disclosures of which are expressly incorporated by reference herein in their entirety.

FIELD OF THE INVENTION

The present invention generally relates to adaptive streaming and more specifically to adaptive bitrate streaming of encoded media contained within Matroska container files using Hypertext Transfer Protocol.

BACKGROUND

The term streaming media describes the playback of media on a playback device, where the media is stored on a server and continuously sent to the playback device over a network during playback. Typically, the playback device stores a sufficient quantity of media in a buffer at any given time during playback to prevent disruption of playback due to the playback device completing playback of all the buffered media prior to receipt of the next portion of media. In many instances, content is divided into multiple streams. For example, content can be divided into audio, video, and subtitle streams and some streams can be encoded as alternative streams that are suitable for different network connection bandwidths or comply with specific geographic restrictions and/or other restrictions.

Adaptive bit rate streaming or adaptive streaming involves detecting the present streaming conditions (e.g. the user's network bandwidth and CPU capacity) in real time and adjusting the quality of the streamed media accordingly by selecting between different streams encoded for use at different network connection data rates. Typically, the source media is encoded at multiple bitrates and the playback device or client switches between streaming the different encodings depending on available resources.

Adaptive streaming solutions typically utilize either Hypertext Transfer Protocol (HTTP), published by the Internet Engineering Task Force and the World Wide Web Consortium as RFC 2616 to stream media between a server and a playback device. HTTP is a stateless protocol that enables a playback device to request a byte range within a file. HTTP is described as stateless, because the server is not required to record information concerning the state of the playback device requesting information or the byte ranges requested by the playback device in order to respond to requests received from the playback device.

In adaptive streaming systems, the source media is typically stored on a media server as a top level index file pointing to a number of alternate streams that contain the actual video and audio data. Each stream is typically stored in one or more container files. Different adaptive streaming solutions typically utilize different index and media containers. The Synchronized Multimedia Integration Language (SMIL) developed by the World Wide Web Consortium is utilized to create indexes in several adaptive streaming solutions including IIS Smooth Streaming developed by Microsoft Corporation of Redmond, Wash., and Flash Dynamic Streaming developed by Adobe Systems Incorporated of San Jose, Calif. HTTP Adaptive Bitrate Streaming developed by Apple Computer Incorporated of Cupertino, Calif. implements index files using an extended M3U playlist file (.M3U8), which is a text file containing a list of URIs that typically identify a media container file. The most commonly used media container formats are the MP4 container format specified in MPEG-4 Part 14 (i.e. ISO/IEC 14496-14) and the MPEG transport stream (TS) container specified in MPEG-2 Part 1 (i.e. ISO/IEC Standard 13818-1). The MP4 container format is utilized in IIS Smooth Streaming and Flash Dynamic Streaming. The TS container is used in HTTP Adaptive Bitrate Streaming.

The Matroska container is a media container developed as an open standard project by the Matroska non-profit organization of Aussonne, France. The Matroska container is based upon Extensible Binary Meta Language (EBML), which is a binary derivative of the Extensible Markup Language (XML). Decoding of the Matroska container is supported by many consumer electronics (CE) devices. The DivX Plus file format developed by DivX, LLC of San Diego, Calif. utilizes an extension of the Matroska container format (i.e. is based upon the Matroska container format, but includes elements that are not specified within the Matroska format).

The term Digital Rights Management (DRM) is utilized to describe access control technologies that are used to control access to and/or copying of digital content. DRM systems typically involve the use of cryptographic information to control access to or protect a piece of content. Content protection is typically achieved using cryptographic information such as (but not limited to) one or more encryption keys to encrypt some or all of the content. An important component of most DRM systems is a mechanism for securely providing cryptographic information to authorized playback devices for use in accessing protected content. The protected content cannot be accessed without the cryptographic data and ideally the cryptographic data is bound to specific playback devices and cannot be readily used by unauthorized playback devices or is securely provided to the playback devices (often on a session basis).

SUMMARY OF THE INVENTION

Systems and methods in accordance with embodiments of the invention perform adaptive bitrate streaming using alter-

native streams of protected content. One embodiment of the invention includes a processor, and memory containing a client application. In addition, the client application configures the processor to: request a top level index file identifying a plurality of alternative streams of protected content, where each of the alternative streams of protected content are encrypted using common cryptographic information; obtain the common cryptographic information; request portions of content from at least the plurality of alternative streams of protected content; access the protected content using the common cryptographic information; and playback the content.

In a further embodiment, the alternative streams of protected content are alternative streams of protected video, each of the alternative streams of protected video includes DRM information indicating portions of frames of video that are encrypted and identifying at least a portion of the common cryptographic information used to access the encrypted portions of the frames of video, and the client application configures the processor to: obtain a protected frame of video from one of the alternative streams of protected video; obtain DRM information indicating a portion of the protected frame of video that is encrypted; identify at least a portion of the common cryptographic information that is used to access the encrypted portion of the protected frame using the DRM information; decrypt the encrypted portion of the protected frame of video using the identified portion of the common cryptographic information; and decode the frame of video.

In another embodiment, each of the alternative streams of protected content is contained within a separate container file, and the top level index file identifies a container file containing each of the alternative streams.

In still further embodiment, the container files containing each of the alternative streams of protected content includes at least one header including the common cryptographic information and information that describes the encoding of the stream of protected content, and the top level index file identifies the location of the at least one header within each container file.

In still another embodiment, the common cryptographic information is a set of encryption keys.

In a yet further embodiment, the common set of encryption keys is encrypted; and the client application configures the processor to securely receive cryptographic information used to unencrypt the common set of encryption keys.

In yet another embodiment, the client application configures the processor to obtain the common cryptographic information by requesting at least one header of a container file identified in the top level index file.

In a further embodiment again, each container file containing one of the alternative streams of protected content further includes an index, and the client application configures the processor to request a portion of content from one of the container files by configuring the processor to: request at least a portion of an index from the container file; identify the portion of the container file containing a specific portion of content using the index; and request the identified portion of the container file.

In another embodiment again, the container files are Matroska container files.

In a further additional embodiment, the common cryptographic information is stored in a common DRM Header element contained within a Tracks element within each of the Matroska container files containing the alternative streams of protected content.

In another additional embodiment, the common cryptographic information is a set of encryption keys; and the set of encryption keys is encrypted and stored within the DRM Header element.

In a still yet further embodiment, the client application configures the processor to: obtain cryptographic information that can be used to unencrypt the set of encryption keys stored within the DRM Header element; and unencrypt the set of encryption keys stored within the DRM Header element using the obtained cryptographic information.

In still yet another embodiment, the client application configures the processor to obtain the DRM Header element by requesting a Tracks element from one of the Matroska container files identified in the top level index file.

In a still further embodiment again, each Mastroska container file containing an alternative stream of protected content further includes an index contained within a Cues element, and the client application configures the processor to request a portion of content from one of the Matroska container files by configuring the processor to: request at least a portion of a Cues element from a Matroska container file containing one of the alternative streams of protected content; identify a portion of the Matroska container file containing a specific portion of content using at least one CueTrackPosition element within the Cues element; and request the portion of the Matroska container file identified by the at least one CueTrackPosition element.

In still another embodiment again, the index includes a plurality of CueTrackPosition elements that identify the location of a plurality of Cluster elements within the Matroska container file.

In a still further additional embodiment, each Cluster element contains a plurality of BlockGroup elements including encoded portions of content, a CueTrack Position element indexes each Cluster element, and each CueTrackPosition element includes the size of the Cluster element that it indexes.

In still another additional embodiment, the alternative streams of protected content are alternative streams of protected video, each of the Matroska container files containing an alternative stream of protected video includes a DRMInfo element in a BlockGroup element containing a protected frame of video, where the DRMInfo element indicates at least a portion of the protected frames of video that is encrypted and identifies at least a portion of the common cryptographic information used to access the at least one encrypted portion of the protected frame of video, and the client application configures the processor to access video frames in a stream of protected video using the common cryptographic information by configuring the processor to: obtain a BlockGroup containing a protected frame of video; parse the BlockGroup element to obtain a DRMInfo element indicating at least a portion of the protected frame of video that is encrypted using an encryption key from the set of encryption keys; decrypt the at least one encrypted portion of the protected frame of video using the identified encryption key; and decode the frame of video.

An embodiment of the method of the invention includes requesting a top level index file identifying a plurality of alternative streams of protected content using a playback device, where each of the alternative streams of protected content are encrypted using common cryptographic information, obtaining the common cryptographic information using the playback device, requesting portions of content from at least the plurality of alternative streams of protected content using the playback device, accessing the protected

content using the playback device and the common cryptographic information, and playing back the content using the playback device.

In a further embodiment of the method of the invention, the alternative streams of protected content are alternative streams of protected video, each of the alternative streams of protected video includes DRM information indicating portions of frames of video that are encrypted and identifying at least a portion of the common cryptographic information used to access the encrypted portions of the frames of video, and the method further includes obtaining a protected frame of video from one of the alternative streams of protected video using the playback device, obtaining DRM information indicating a portion of the protected frame of video that is encrypted using the playback device, identify at least a portion of the common cryptographic information that is used to access the encrypted portion of the protected frame using the playback device and the DRM information, decrypting the encrypted portion of the protected frame of video using the playback device and the identified portion of the common cryptographic information, and decoding the frame of video using the playback device.

In another embodiment of the method of the invention, each of the alternative streams of protected content is contained within a separate container file, and the top level index file identifies a container file containing each of the alternative streams.

In a still further embodiment of the method of the invention, the container files containing each of the alternative streams of protected content include at least one header including the common cryptographic information and information that describes the encoding of the stream of protected content, and the top level index file identifies the location of the at least one header within each container file.

In still another embodiment of the method of the invention, the common cryptographic information is a set of encryption keys.

In a yet further embodiment of the method of the invention, the set of encryption keys is encrypted so that it is accessible using cryptographic information obtained by the playback device, and the method further comprising obtaining cryptographic information using the playback device.

In yet another embodiment of the method of the invention, the set of encryption keys is encrypted using at least one encryption key, and the playback device securely obtains the at least one encryption key.

In a further embodiment again of the method of the invention, the at least one encryption key is encrypted using at least one encryption key included in the cryptographic information bound to the playback device.

Another embodiment again of the method of the invention also includes obtaining the common cryptographic information by requesting at least one header of a container file identified in the top level index file using the playback device.

In a further additional embodiment of the method of the invention, each container file containing one of the alternative streams of protected content further includes an index, and the method further includes: requesting at least a portion of an index from the container file using the playback device; identify the portion of the container file containing a specific portion of content using the playback device and the index; and requesting the identified portion of the container file using the playback device.

In another additional embodiment of the method of the invention, the container files are Matroska container files.

In a still yet further embodiment of the method of the invention, the common cryptographic information is stored in a common DRM Header element contained within a Tracks element within each of the Matroska container files containing the alternative streams of protected content.

In still yet another embodiment of the method of the invention, the common cryptographic information is a set of encryption keys, and the set of encryption keys is encrypted and stored within the DRM Header element.

In a still further embodiment again of the method of the invention, the set of encryption keys is encrypted so that it is accessible using cryptographic information obtained by the playback device, and the method further comprising obtaining cryptographic information using the playback device.

Still another embodiment again of the method of the invention also includes obtaining the DRM Header element by requesting a Tracks element from one of the Matroska container files identified in the top level index file.

In a still further additional embodiment of the method of the invention, each Mastroska container file containing an alternative stream of protected content further includes an index contained within a Cues element, and the method further includes: requesting at least a portion of a Cues element from a Matroska container file containing one of the alternative streams of protected content using the playback device; identifying a portion of the Matroska container file containing a specific portion of content using the playback device and at least one CueTrackPosition element within the Cues element; and requesting the portion of the Matroska container file identified by the at least one CueTrackPosition element.

In still another additional embodiment of the method of the invention, the index includes a plurality of CueTrackPosition elements that identify the location of a plurality of Cluster elements within the Matroska container file.

In a yet further embodiment again of the method of the invention, each Cluster element contains a plurality of BlockGroup elements including encoded portions of content, a CueTrack Position element indexes each Cluster element, and each CueTrackPosition element includes the size of the Cluster element that it indexes.

In yet another embodiment again of the method of the invention, the alternative streams of protected content are alternative streams of protected video, each of the Matroska container files containing an alternative stream of protected video includes a DRMInfo element in a BlockGroup element containing a protected frame of video, where the DRMInfo element indicates at least a portion of the protected frames of video that is encrypted and identifies at least a portion of the common cryptographic information used to access the at least one encrypted portion of the protected frame of video, and the method further includes: obtaining a BlockGroup containing a protected frame of video using the playback device; parsing the BlockGroup element to obtain a DRMInfo element indicating at least a portion of the protected frame of video that is encrypted using the playback device and an encryption key from the set of encryption keys; decrypting the at least one encrypted portion of the protected frame of video using the playback device and the identified encryption key; and decoding the frame of video using the playback device.

Another further embodiment includes a machine readable medium containing processor instructions, where execution of the instructions by a processor causes the processor to perform a process including request a top level index file identifying a plurality of alternative streams of protected

content, where each of the alternative streams of protected content are encrypted using common cryptographic information, obtaining the common cryptographic information, requesting portions of content from at least the plurality of alternative streams of protected content, accessing the protected content using the common cryptographic information, and playing back the content.

In still another further embodiment, the alternative streams of protected content are alternative streams of protected video, each of the alternative streams of protected video includes DRM information indicating portions of frames of video that are encrypted and identifying at least a portion of the common cryptographic information used to access the encrypted portions of the frames of video, and execution of the instructions by a processor also causes the processor to perform a process including: obtaining a protected frame of video from one of the alternative streams of protected video; obtaining DRM information indicating a portion of the protected frame of video that is encrypted; identify at least a portion of the common cryptographic information that is used to access the encrypted portion of the protected frame using the DRM information; decrypting the encrypted portion of the protected frame of video using and the identified portion of the common cryptographic information; and decoding the frame of video.

In yet another further embodiment, the machine readable medium is non-volatile memory.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a network diagram of an adaptive bitrate streaming system in accordance with an embodiment of the invention.

FIG. **1**B is a block diagram illustrating a source encoder in accordance with an embodiment of the invention.

FIG. **1**C is a block diagram illustrating a content distribution server in accordance with an embodiment of the invention.

FIG. **1**D is a block diagram illustrating a playback device in accordance with an embodiment of the invention.

FIG. **2** conceptually illustrates a top level index file and Matroska container files generated by the encoding of source media in accordance with embodiments of the invention.

FIG. **3** conceptually illustrates a specialized Matroska container file incorporating a TracksData Payload containing cryptographic information in accordance with an embodiment of the invention.

FIGS. **4***a*-**4***c* conceptually illustrate the insertion of different types of protected media into the Clusters element of a Matroska container file subject to various constraints that facilitate adaptive bitrate streaming in accordance with embodiments of the invention.

FIG. **4***d* conceptually illustrates the multiplexing of different types of protected media into the Clusters element of a Matroska container file subject to various constraints that facilitate adaptive bitrate streaming in accordance with an embodiment of the invention.

FIG. **4***e* conceptually illustrates the inclusion of a protected trick play track into the Clusters element of a Matroska container file subject to various constraints that facilitate adaptive bitrate streaming in accordance with an embodiment of the invention.

FIG. **5** conceptually illustrates a modified Cues element of a specialized Matroska container file, where the Cues element includes information enabling the retrieval of Cluster elements using HTTP byte range requests in accordance with an embodiment of the invention.

FIG. **5***a* conceptually illustrates a modified Cues element of a specialized Matroska container file in accordance with an embodiment of the invention, where the Cues element is similar to the Cues element shown in FIG. **5** with the exception that attributes that are not utilized during adaptive bitrate streaming are removed.

FIG. **6** conceptually illustrates the indexing of Cluster elements within a specialized Matroska container file utilizing modified CuePoint elements within the container file in accordance with embodiments of the invention.

FIG. **7** conceptually illustrates the use of a hierarchical index to index CuePoint elements within a Matroska container file in accordance with embodiments of the invention.

FIG. **8** is a flow chart illustrating a process for encoding and protecting source media for adaptive bitrate streaming in accordance with an embodiment of the invention.

FIG. **9** is a flow chart illustrating a process for encoding and encrypting frames of source video in accordance with an embodiment of the invention.

FIG. **10** conceptually illustrates a DRM header element that can be included in a Matroska container file in accordance with an embodiment of the invention.

FIG. **11** conceptually illustrates communication between a playback device and an HTTP server associated with the commencement of streaming of encoded media contained within Matroska container files indexed by a top level index file in accordance with an embodiment of the invention.

FIGS. **12***a* and **12***b* conceptually illustrate communication between a playback device and an HTTP server associated with switching between streams in response to the streaming conditions experienced by the playback device prior to the decision to switch streams in accordance with embodiments of the invention.

DETAILED DISCLOSURE OF THE INVENTION

Turning now to the drawings, systems and methods for performing adaptive bitrate streaming using alternative streams of protected content in accordance with embodiments of the invention are illustrated. In a number of embodiments, source media is encoded as a number of alternative streams and the alternative streams are protected using a common set of cryptographic information. In many embodiments, the alternative streams are video streams and each stream is protected by encrypting at least a portion of a plurality of video frames within the stream using the common set of cryptographic information. In several embodiments, the common set of cryptographic information is a set of frame keys. In order to protect a video frame, a frame key can be selected from the set of frame keys and used to encrypt at least a portion of the encoded frame and DRM information can be provided with the protected frame indicating the frame key utilized to perform the encryption and the location of the encrypted portion within the frame. By encrypting each of the alternative streams using the same set of cryptographic information, a playback device can switch between streams without the need to maintain or acquire multiple sets of cryptographic information in memory or to reinitialize the decryption engine of the playback device with a different set of cryptographic information.

In many embodiments, each of the alternative streams is stored in a separate container file referenced by a top level index file. In several embodiments, the common cryptographic information is embedded in each of the container files so that a playback device has access to the cryptographic information irrespective of which alternative is

initially select to commence playback of the media. The common cryptographic information can be stored on a content distribution system and associated with a title identifier or title ID that uniquely identifies the source content used to create the alternative streams. When a new alternative stream is generated, a source encoder can utilize the title ID to request the common cryptographic information from the content distribution system and the common cryptographic information can be utilized to encrypt the new alternative stream and embedded in a container file created to contain the new encrypted alternative stream.

In several embodiments, each stream associated with a piece of source content and/or title ID is stored in a Matroska (MKV) container file. In many embodiments, the Matroska container file is a specialized Matroska container file in that the manner in which the media in each stream is encoded and stored within the container is constrained to improve streaming performance. In several embodiments, the Matroska container file is further specialized in that additional DRM elements (i.e. elements that are not specified as part of the Matroska container format) can be included within the file to facilitate the distribution of protected media during adaptive bitrate streaming. In a number of embodiments, common cryptographic information is included within a DRM header element in each of the Matroska container files and references to the common cryptographic information are made using DRMInfo elements within a BlockGroup element corresponding to a specific frame of encrypted video. In other embodiments, any of a variety of mechanisms can be utilized to store DRM information within a Matroska container in accordance with embodiments of the invention. In several embodiments, each stream (i.e. audio, video, or subtitle) is stored within a separate Matroska container file. In other embodiments, an encoded video stream is multiplexed with one or more encoded audio, and/or subtitle streams in each Matroska container file.

A top level index file containing an index to the streams contained within each of the container files is also generated to enable adaptive bitrate streaming of the encoded media. In many embodiments, the top level index file is a Synchronized Multimedia Integration Language (SMIL) file containing URIs for each of the Matroska container files. In other embodiments, any of a variety of file formats can be utilized in the generation of the top level index file.

The performance of an adaptive bitstrate streaming system in accordance with embodiments of the invention can be significantly enhanced by encoding each portion of the source video at each bit rate in such a way that the portion of video is encoded in each stream as a single (or at least one) closed group of pictures (GOP) starting with an Instantaneous Decoder Refresh (IDR) frame. The GOP for each stream can then be stored as a Cluster element within the Matroska container file for the stream. In this way, the playback device can switch between streams at the completion of the playback of a Cluster and, irrespective of the stream from which a Cluster is obtained the first frame in the Cluster will be an IDR frame and can be decoded without reference to any encoded media other than the encoded media contained within the Cluster element. In many embodiments, the sections of the source video that are encoded as GOPs are all the same duration. In a number of embodiments each two second sequence of the source video is encoded as a GOP.

Adaptive streaming of source media encoded in the manner outlined above can be coordinated by a playback device in accordance with embodiments of the invention. The playback device obtains information concerning each of the available streams from the top level index file and selects one or more streams to utilize in the playback of the media. The playback device can then obtain header information from the Matroska container files containing the one or more bitstreams or streams, and the headers provide information concerning the decoding of the streams including a DRM header, which contains the cryptographic information utilized to protect the stream. The playback device can also request index information that indexes the encoded media stored within the relevant Matroska container files. The index information can be stored within the Matroska container files or separately from the Matroska container files in the top level index or in separate index files. The index information enables the playback device to request byte ranges corresponding to Cluster elements within the Matroska container file containing specific portions of encoded media via HTTP from the server. As the playback device receives the Cluster elements from the HTTP server, the playback device can evaluate current streaming conditions to determine whether to increase or decrease the bitrate of the streamed media. In the event that the playback device determines that a change in bitrate is necessary, the playback device can obtain header information and index information for the container file(s) containing the desired stream(s) (assuming the playback device has not already obtained this information). The playback device need not perform the computationally intensive process of accessing the encrypted cryptographic information in the header of the new stream, because each of the alternative streams uses common cryptographic information. The index information can then be used to identify the byte range of the Cluster element containing the next portion of the source media encoded at the desired bit rate and the identified Cluster element can be retrieved from the server via HTTP. The next portion of the source media that is requested is typically identified based upon the Cluster elements already requested by the playback device and the Cluster elements buffered by the playback device. The next portion of source media requested from the alternative stream is requested to minimize the likelihood that the buffer of the playback device will underflow (i.e. run out media to playback) prior to receipt of the Cluster element containing the next portion of source media by the playback device. In this way, the playback device can achieve adaptive bitrate streaming by retrieving sequential Cluster elements from the various streams as appropriate to the streaming conditions using the top level index and index information describing the Cluster elements within each of the Matroska container files.

In a number of embodiments, variation in the bitrate between different streams can be achieved by modifying the encoding parameters for each stream including but not limited to the bitrate, frame rate, resolution and sample aspect ratio. The encoding and protection of source video using common cryptographic information for use in adaptive bitrate streaming and the playback of alternative streams of protected content via adaptive bitrate streaming in accordance with embodiments of the invention is discussed further below.

Adaptive Streaming System Architecture

An adaptive bitrate streaming system in accordance with an embodiment of the invention is illustrated in FIG. **1**. The adaptive streaming system **10** includes a source encoder **12** configured to encode source media as a number of alternative streams and to protect the encoded streams using common cryptographic information. Alternative streams are streams that encode the same media content in different

ways. In several embodiments, the source encoder **12** ingests source content and obtains a title ID and common cryptographic information from a content distribution server **14** that the content distribution server assigns to the source content. The source encoder encodes the alternative streams and protects the streams using the common cryptographic information received from the content distribution server. In many instances, alternative streams encode media content (such as but not limited to video) at different maximum bitrates. In a number of embodiments, the alternative streams are encoded with different resolutions, sample aspect ratios and/or frame rates. When the streams are written to file(s), the common cryptographic information is also written to the file(s). The content distribution server **14** can receive request to access the alternative streams of content (i.e. the title) via the Internet from a playback device such as (but not limited to) a user computer **18** or a mobile phone **20** and can commence streaming content. In several embodiments, the common cryptographic information is protected by encrypting at least a portion of the common cryptographic information using at least one encryption key. The playback device can securely obtain the cryptographic key using a process such as (but not limited to) Hypertext Transfer Protocol Secure or HTTPS. Other processes for securely obtaining cryptographic information to obtain access to encrypted common cryptographic information in accordance with embodiments of the invention are discussed below.

In many embodiments, a playback device commences playback by requesting a top level index file from the content distribution server. The source encoder **12**, the content distribution server **14**, or another server can generate the top level index to the file(s) containing the streams, at least a plurality of which are alternative streams, at the time the request is made or at the time the streams are generated by the source encoder. The playback device can then use HTTP or another appropriate stateless protocol to request portions of the top level index file and the file(s) containing the protected streams via a network **16** such as the Internet.

In many embodiments, the top level index file is a SMIL file and the media is stored in Matroska container files. As is discussed further below, the media can be stored within the Matroska container file in a way that facilitates the protection of the content using common cryptographic information. In many embodiments, the Matroska container files are specialized Matroska container files that include enhancements (i.e. elements that do not form part of the Matroska file format specification) that facilitate retrieval and decryption using common cryptographic information of specific portions of media during adaptive bitrate streaming.

Although a specific content distribution system configured to support adaptive bitrate streaming is illustrated in FIG. **1**A, any of a variety of content distribution system architectures can be utilized to implement an adaptive bitrate streaming system in accordance with embodiments of the invention. Source encoders, content distribution server systems, and playback devices in accordance with embodiments of the invention are discussed further below.

Source Encoders

In many embodiments, a source encoder can be implemented using a server. In other embodiments, the source encoder can be any processing device including a processor and sufficient resources to perform the transcoding and encryption of source media (including but not limited to video, audio, and/or subtitles). A source encoder in accordance with an embodiment of the invention is illustrated in FIG. **1**B. The source encoder **12** is implemented on a computing platform including a processor **12***a*, volatile memory **12***b* and non-volatile storage **12***c*. An encoder application **12***d* is stored in non-volatile storage **12***c*. The encoder application includes the machine readable instructions that configure the processor to encode source content **12***e* as a plurality of streams. In a number of embodiments, the encoder application also configures the source encoder to obtain common cryptographic information **12***g* that can be utilized to protect alternative streams generated using the source content **12***e*. In many embodiments, the source encoder obtains the common cryptographic information and a title ID from a content distribution system. In other embodiments, the source encoder generates a title ID and/or cryptographic data and provides the generated information to a content distribution system.

Although a specific source encoder in accordance with embodiments of the invention is illustrated in FIG. **1**B, any of a variety of computing platforms can be utilized to implement a source encoder that is configured to encode at least one stream of source content as a plurality of alternative streams and to protect each of the alternative streams using common cryptographic information in accordance with embodiments of the invention.

Content Distribution Servers

Content distribution servers in accordance with embodiments of the invention can be responsible for storing protected streams of content for streaming to playback devices using adaptive bitrate streaming processes. Content distribution servers can also store common cryptographic information utilized to protect the alternative streams of protected content. In several embodiments, the common cryptographic information is identified utilizing a title ID associated with the common cryptographic information and a set of streams that form part of a specific title or piece of content. A content distribution server in accordance with an embodiment of the invention is illustrated in FIG. **1**C. The content distribution server is implemented using a computing platform including a processor **14***a*, volatile memory **14***b*, and non-volatile storage **14***c*. In the illustrated embodiment, a plurality of container files **14***d* are stored on the content distribution server. Playback devices can stream content from the content distribution server utilizing adaptive bitrate streaming processes in accordance with embodiments of the invention. To facilitate the creation of new streams with respect to a specific piece of content, the content distribution server also stores title IDs **14***e* for specific pieces of content and common cryptographic information **14***f* associated with each title ID. A source encoder can request common cryptographic information to protect a new stream related to a specific piece of content, by providing a request to the content distribution server that identifies the specific piece of content using the title ID assigned to it.

Although a specific content distribution server is illustrated in FIG. **1**C, any of a variety of computational platform including (but not limited to) platforms in which container files and common cryptographic information are stored on separate servers can be utilized in content distribution systems in accordance with embodiments of the invention.

Playback Devices

Referring back to FIG. **1**A, the illustrated playback devices include personal computers **18** and mobile phones **20**. In other embodiments, playback devices can include consumer electronics devices such as DVD players, Blu-ray players, televisions, set top boxes, video game consoles, tablets, and other devices that are capable of playing back protected media stored on a content distribution server using adaptive bitrate streaming. A playback device in accordance

with an embodiment of the invention is illustrated in FIG. **1**D. The playback device is implemented on a processing platform **20** including a processor **20***a*, volatile memory **20***b*, and non-volatile memory (or other non-volatile storage) **20***c*. The non-volatile memory **20***c* contains a client application **20***d*, which includes machine readable instructions that can be utilized to configure the processor to register with a content distribution system to obtain cryptographic data **20***e* bound to the playback device. The playback device can then use the bound cryptographic data **20***e* to request adaptive bitrate streaming of protected content. As is discussed further below, the alternative streams of protected content utilized to perform adaptive bitrate streaming are protected using common cryptographic information. Once the client application **20***d* has obtained the common cryptographic information, which can be a time consuming and/or computationally intensive process, the playback device can use the same cryptographic information to access content in any of the alternative streams of protected content within a single instance of a title.

Although a specific architecture for a playback device is shown in FIG. **1**D any of a variety of architectures can be utilized that enable playback devices to request portions of the top level index file and the container files in accordance with embodiments of the invention.

File Structure

Files generated by a source encoder and/or stored on an HTTP server for streaming to playback devices in accordance with embodiments of the invention are illustrated in FIG. **2**. The files utilized in the adaptive bitrate streaming of the source media include a top level index **30** and a plurality of container files **32** that each contain at least one stream. The top level index file describes the content of each of the container files. As is discussed further below, the top level index file can take a variety of forms including an SMIL file and the container files can take a variety of forms including a specialized Matroska container file.

In many embodiments, each Matroska container file contains a single protected stream. For example, the stream could be one of a number of alternate video streams protected using common cryptographic information, an audio stream, one of a number of alternate audio streams, a subtitle stream, one of a number of alternate subtitle streams, a trick play stream, or one of a number of alternate trick play streams protected using common cryptographic information. In several embodiments, the Matroska container file includes multiple multiplexed streams. For example, the Matroska container could include a video stream, and one or more audio streams, one or more subtitle streams, and/or one or more trick play streams. As is discussed further below, in many embodiments the Matroska container files are specialized files. The encoding of the media and the manner in which the media is stored within Cluster elements within the Matroska container file can be subject to constraints designed to enhance the performance of an adaptive bitrate streaming system. In a number of embodiments, common cryptographic information is included within a DRM header element in each of the Matroska container files and references to the common cryptographic information are made using DRMInfo elements included within BlockGroup elements of protected (not all frames need be protected to protect the stream). In addition, the Matroska container file can include index elements that facilitate the location and downloading of Cluster elements from the various Matroska container files during the adaptive streaming of the media. Top level index files and Matroska container files that can be used in adaptive bitrate streaming systems in accordance with embodiments of the invention are discussed below.

Top Level Index Files

Playback devices in accordance with many embodiments of the invention utilize a top level index file to identify the container files that contain the streams available to the playback device for use in adaptive bitrate streaming. In many embodiments, the top level index files can include references to container files that each include an alternative stream of encoded media. The playback device can utilize the information in the top level index file to retrieve encoded media from each of the container files according to the streaming conditions experienced by the playback device.

In several embodiments, the top level index file provides information enabling the playback device to retrieve information concerning the encoding of the media in each of the container files and an index to encoded media within each of the container files. In a number of embodiments, each container file includes information concerning the encoded media contained within the container file and an index to the encoded media within the container file and the top level index file indicates the portions of each container file containing this information. Therefore, a playback device can retrieve the top level index file and use the top level index file to request the portions of one or more of the container files that include information concerning the encoded media contained within the container file and an index to the encoded media within the container file. A variety of top level index files that can be utilized in adaptive bitrate streaming systems in accordance with embodiments of the invention are discussed further below.

In a number of embodiments, the top level index file utilized in the adaptive bitrate streaming of media is a SMIL file, which is an XML file that includes a list of URIs describing each of the streams and the container files that contain the streams. The URI can include information such as the "system-bitrate" of the stream contained within the stream and information concerning the location of specific pieces of data within the container file. The top level index SMIL file can be generated when the source media is encoded for playback via adaptive bitrate streaming. Alternatively, the top level index SMIL file can be generated when a playback device requests the commencement of playback of the encoded media. When the playback device receives the top level index SMIL file, the playback device can parse the SMIL file to identify the available streams. The playback device can then select the streams to utilize to playback the content and can use the SMIL file to identify the portions of the container file to download to obtain information concerning the encoding of a specific stream and/or to obtain an index to the encoded media within the container file.

Although top level index SMIL files are described above, any of a variety of top level index file formats can be utilized to create top level index files as appropriate to a specific application in accordance with an embodiment of the invention. The use of top level index files to enable playback of encoded media using adaptive bitrate streaming in accordance with embodiments of the invention is discussed further below.

Storing Protected Media in MKV Files for Adaptive Bitrate Streaming

A Matroska container file used to store encoded video in accordance with an embodiment of the invention is illustrated in FIG. **3**. The container file **32** is an Extensible Binary Markup Language (EBML) file that is an extension of the Matroska container file format. The specialized Matroska

container file **32** includes a standard EBML element **34**, and a standard Segment element **36** that includes a standard Seek Head element **40**, a standard Segment Information element **42**, and a standard Tracks element **44** including a tracks data payload that is a non-standard EBML element containing cryptographic information utilized to access the protected stream(s) contained within the Matroska container file. In many embodiments, the cryptographic data takes the form of a DRMHeaders element (discussed below) that includes a set of keys utilized to access encrypted portions of the stream contained within the Matroska container file. In many embodiments, the set of keys is encrypted in such a way that a playback device can only access the set of keys in the clear using a specific piece or set of cryptographic information.

The Segment element **36** also includes a standard Clusters element **46**. As is described below, the manner in which encoded media is inserted within individual Cluster elements **48** within the Clusters element **46** is constrained to improve the playback of the media in an adaptive streaming system. In many embodiments, the constraints imposed upon the encoded video are consistent with the specification of the Matroska container file format and involve encoding the video so that each cluster includes at least one closed GOP commencing with an IDR frame. In addition to the above elements, the Segment element **36** can optionally include a modified version of the standard Cues element. As is discussed further below, the Cues element includes specialized CuePoint elements (i.e. non-standard CuePoint elements) that facilitate the retrieval of the media contained within specific Cluster elements via HTTP. The Segment element **36** can optionally include a non-standard Hierarchical Index element **54**. The Hierarchical Index element is an extension to the Matroska file format proposed by DivX, LLC of San Diego, Calif. The Hierarchical Index element is described in U.S. patent application Ser. No. 12/272,631, the disclosure of which is incorporated by reference above in its entirety.

The constraints imposed upon the encoding of media and the formatting of the encoded media within the Clusters element of a Matroska container file for adaptive bitrate streaming of protected streams and the additional DRM and index information inserted within the container file in accordance with embodiments of the invention are discussed further below.

Encoding Media for Insertion in Cluster Elements

An adaptive bitrate streaming system provides a playback device with the option of selecting between different protected streams of encoded media during playback according to the streaming conditions experienced by the playback device. In many embodiments, switching between protected streams is facilitated by separately pre-encoding discrete portions of the source media in accordance with the encoding parameters of each stream and then including each separately encoded portion in its own Cluster element within the stream's container file. Furthermore, the media contained within each Cluster is encoded so that the media is capable of playback without reference to media contained in any other Cluster within the stream. In this way, each stream includes a Cluster element corresponding to the same discrete portion of the source media and, at any time, the playback device can select the Cluster element from the stream that is most appropriate to the streaming conditions experienced by the playback device and can commence playback of the media contained within the Cluster element. Accordingly, the playback device can select clusters from different streams as the streaming conditions experienced by the playback device change over time. In several embodiments, the Cluster elements are further constrained so that each Cluster element contains a portion of encoded media from the source media having the same duration. In a number of embodiments, each Cluster element includes two seconds of encoded media. The specific constraints applied to the media encoded within each Cluster element depending upon the type of media (i.e. video, audio, or subtitles) are discussed below.

A Clusters element of a Matroska container file containing a video stream in accordance with an embodiment of the invention is illustrated in FIG. **4***a*. The Clusters element **46** includes a plurality of Cluster elements **48** that each contains a discrete portion of encoded video. In the illustrated embodiment, each Cluster element **48** includes two seconds of encoded video. In other embodiments, the Cluster elements include encoded video having a greater or lesser duration than two seconds. In several embodiments, the encoded video sequences in the Cluster elements have different durations.

Each Cluster element **48** includes a Timecode element **60** indicating the start time of the encoded video within the Cluster element and a plurality of BlockGroup elements. As noted above, the encoded video stored within the Cluster is constrained so that the encoded video can be played back without reference to the encoded video contained within any of the other Cluster elements in the container file. In many embodiments, encoding the video contained within the Cluster element as a GOP in which the first frame is an IDR frame enforces the constraint. In the illustrated embodiment, the first BlockGroup element **62** contains an IDR frame. Therefore, the first BlockGroup element **62** does not include a ReferenceBlock element. The first BlockGroup element **62** includes a Block element **64**, which specifies the Timecode attribute of the frame encoded within the Block element **64** relative to the Timecode of the Cluster element **48** and a DRMInfo element **65** that identifies a portion of the frame that is encrypted and the cryptographic information that can be utilized to access the encrypted portion of the frame. In a number of embodiments, only a small portion of the video frame is encrypted and the DRMInfo includes a reference to the start of an encrypted block of data and the size of the encrypted block of data. As is discussed further below, the common cryptographic information utilized to protect alternative streams of video content is a set of frame keys in many embodiments of the invention and the DRMInfo element can also include an index to a specific frame key in the set of frame keys that can be utilized to access the encrypted block of data in the clear. In other embodiments, any of a variety of information appropriate to identifying encrypted data within a video frame and decrypting the encrypted data can be stored within a DRMInfo element.

Subsequent BlockGroup elements **66** are not restricted in the types of frames that they can contain (other than that they cannot reference frames that are not contained within the Cluster element). Therefore, subsequent BlockGroup elements **66** can include ReferenceBlock elements **68** referencing other BlockGroup element(s) utilized in the decoding of the frame contained within the BlockGroup or can contain IDR frames and are similar to the first BlockGroup element **62**. In addition, subsequent BlockGroup elements **66** can also include DRMInfo elements to describe the manner in which the frame of video contained within the BlockGroup element is protected. As noted above, the manner in which encoded video is inserted within the Cluster elements of the Matroska file conforms with the specification of the Matroska file format.

The insertion of encoded audio and subtitle information within a Clusters element **46** of a Matroska container file in accordance with embodiments of the invention is illustrated in FIGS. **4***b* and **4***c*. In the illustrated embodiments, the encoded media is inserted within the Cluster elements **48** subject to the same constraints applied to the encoded video discussed above with respect to FIG. **4***a*. In addition, the duration of the encoded audio and subtitle information within each Cluster element corresponds to the duration of the encoded video in the corresponding Cluster element of the Matroska container file containing the encoded video. In other embodiments, the Cluster elements within the container files containing the audio and/or subtitle streams need not correspond with the start time and duration of the Cluster elements in the container files containing the alternative video streams. In many embodiments, audio, and/or subtitle tracks are protected and information identifying the protected portions of the stream can be included in an element in a manner similar to that described above with respect to protected video streams.

Muliplexing Streams in a Single MKV Container File

The Clusters elements shown in FIGS. **4***a*-**4***c* assume that a single stream is contained within each Matroska container file. In several embodiments, media from multiple streams is multiplexed within a single Matroska container file. In this way, a single container file can contain a video stream multiplexed with one or more corresponding audio streams, and/or one or more corresponding subtitle streams. Storing the streams in this way can result in duplication of the audio and subtitle streams across multiple alternative video streams. However, the seek time to retrieve encoded media from a video stream and an associated audio, and/or subtitle stream can be reduced due to the adjacent storage of the data on the server. The Clusters element **46** of a Matroska container file containing multiplexed video, audio and subtitle data in accordance with an embodiment of the invention is illustrated in FIG. **4***d*. In the illustrated embodiment, each Cluster element **48** includes additional BlockGroup elements for each of the multiplexed streams. The first Cluster element includes a first BlockGroup element **62***v* for encoded video that includes a Block element **64***v* containing an encoded video frame and indicating the Timecode attribute of the frame relative to the start time of the Cluster element (i.e. the Timecode attribute **60**). A second BlockGroup element **62***a* includes a Block element **64***a* including an encoded audio sequence and indicating the timecode of the encoded audio relative to the start time of the Cluster element, and a third BlockGroup element **62***s* including a Block element **64***s* containing an encoded subtitle and indicating the timecode of the encoded subtitle relative to the start time of the Cluster element. In the illustrated embodiment, only the video stream is protected. Therefore, the BlockGroup elements **62***v* containing the video stream include DRMInfo elements **65***v* to identify the portions of the frames within the video stream that are encrypted. In other embodiments, the audio, and/or subtitle streams can also be protected. Although not shown in the illustrated embodiment, each Cluster element **48** likely would include additional BlockGroup elements containing additional encoded video, audio or subtitles. Despite the multiplexing of the encoded video, audio, and/or subtitle streams, the same constraints concerning the encoded media apply.

Incorporating Trick Play Streams in MKV Container Files for Use in Adaptive Bitrate Streaming Systems

The incorporation of trick play tracks within Matroska container files is proposed by DivX, LLC in U.S. patent application Ser. No. 12/260,404 entitled "Application Enhancement Tracks", filed Oct. 29, 2008, the disclosure of which is hereby incorporated by reference in its entirety. Trick play tracks similar to the trick play tracks described in U.S. patent application Ser. No. 12/260,404 can be used to provide a trick play stream in an adaptive bitrate streaming system in accordance with an embodiment of the invention to provide smooth visual search through source content encoded for adaptive bitrate streaming. A separate trick play stream can be encoded that appears to be an accelerated visual search through the source media when played back, when in reality the trick play stream is simply a separate stream encoding the source media at a lower frame rate. In several embodiments, a trick play stream is generated in the manner outlined in U.S. patent application Ser. No. 12/260,404 and inserting the trick play stream into a Matroska container file subject to the constraints mentioned above with respect to insertion of a video stream into a Matroksa container file. In many embodiments, the trick play stream is also subject to the further constraint that every frame in the GOP of each Cluster element in the trick play stream is encoded as an IDR frame. As with the other video streams, each Cluster element contains a GOP corresponding to the same two seconds of source media as the corresponding Cluster elements in the other streams. There are simply fewer frames in the GOPs of the trick play stream and each frame has a longer duration. In this way, transitions to and from a trick play stream can be treated in the same way as transitions between any of the other encoded streams are treated within an adaptive bitrate streaming system in accordance with embodiments of the invention. In embodiments where the trick play stream(s) are protected, the same common cryptographic information utilized to encrypt the primary video stream(s) is utilized to protect the trick play stream(s). Playback of the frames contained within the trick play stream to achieve accelerated visual search typically involves the playback device manipulating the timecodes assigned to the frames of encoded video prior to providing the frames to the playback device's decoder to achieve a desired increase in rate of accelerated search (e.g. ×2, ×4, ×6, etc.).

A Clusters element containing encoded media from a trick play stream is shown in FIG. **4***e*. In the illustrated embodiment, the encoded trick play stream is inserted within the Cluster elements **48** subject to the same constraints applied to the encoded video discussed above with respect to FIG. **4***a* including the constraint that frames are protected using the common cryptographic information. However, each BlockGroup element contains an IDR. In other embodiments, the Cluster elements within the container files containing the trick play streams need not correspond with the start time and duration of the Cluster elements in the container files containing the alternative video streams.

In many embodiments, source content can be encoded to provide a single trick play stream or multiple trick play streams for use by the adaptive bit rate streaming system. When a single trick play stream is provided, the trick play stream is typically encoded at a low bitrate. When multiple alternative trick play streams are provided, adaptive streaming can also be performed with respect to the trick play streams. In several embodiments, multiple trick play streams are provided to support different rates of accelerated visual search through the encoded media.

Incorporating Indexing Information within MKV Container Files

The specification for the Matroska container file format provides for an optional Cues element that is used to index Block elements within the container file. A modified Cues

element that can be incorporated into a Matroska container file in accordance with an embodiment of the invention to facilitate the requesting of clusters by a playback device using HTTP is illustrated in FIG. **5**. The Cues element **52** is similar to a standard Cues element **52** in that it includes a plurality of standard CuePoint elements **70** that each include a standard CueTime attribute **72**. Each CuePoint element includes a CueTrackPositions element **74** containing the standard CueTrack **76** and CueClusterPosition **78** attributes. In many embodiments, the CuePoint element is mainly configured to identify a specific Cluster element as opposed to a specific Block element within a Cluster element. Although, in several applications the ability to seek to specific Block elements within a Cluster element is required and additional index information is included in the Cues element.

The use of a modified Cues element to index encoded media within a Clusters element of a Matroska file in accordance with an embodiment of the invention is illustrated in FIG. **6**. A CuePoint element is generated to correspond to each Cluster element within the Matroska container file. The CueTime attribute **72** of the CuePoint element **70** corresponds to the Timecode attribute **60** of the corresponding Cluster element **48**. In addition, the CuePoint element contains a CueTrackPositions element **74** having a CueClusterPosition attribute **78** that points to the start of the corresponding Cluster element **48**. The CueTrackPositions element **74** can also include a CueBlockNumber attribute, which is typically used to indicate the Block element containing the first IDR frame within the Cluster element **48**.

As can readily be appreciated the Cues element **52** forms an index to each of the Cluster elements **48** within the Matroska container file. Furthermore, the CueTrackPosition elements provide information that can be used by a playback device to request the byte range of a specific Cluster element **48** via HTTP or another suitable protocol from a remote server. The Cues element of a conventional Matroska file does not directly provide a playback device with information concerning the number of bytes to request from the start of the Cluster element in order to obtain all of the encoded video contained within the Cluster element. The size of a Cluster element is, therefore, inferred by using the CueClusterPosition attribute of the CueTrackPositions element that indexes the first byte of the next Cluster element. Alternatively, additional CueTrackPosition elements could be added that index the last byte of the Cluster element (in addition to the CueTrackPositions elements that index the first byte of the Cluster element), and/or a non-standard CueClusterSize attribute that specifies the size of the Cluster element pointed to by the CueClusterPosition attribute is included in each CueTrackPosition element to assist with the retrieval of specific Cluster elements within a Matroska container file via HTTP byte range requests or a similar protocol.

The modification of the Cues element in the manner outlined above significantly simplifies the retrieval of Cluster elements from a Matroska container file via HTTP or a similar protocol during adaptive bitrate streaming. In addition, by only indexing the first frame in each Cluster the size of the index is significantly reduced. Given that the index is typically downloaded prior to playback, the reduced size of the Cues element (i.e. index) means that playback can commence more rapidly. Using the CueClusterPosition elements, a playback device can request a specific Cluster element from the stream most suited to the streaming conditions experienced by the playback device by simply referencing the index of the relevant Matroska container file using the Timecode attribute for the desired Cluster element.

A number of the attributes within the Cues element are not utilized during adaptive bitrate streaming. Therefore, the Cues element can be further modified by removing the unutilized attributes to reduce the overall size of the index for each Matroska container file. A modified Cues element that can be utilized in a Matroska container file that includes a single encoded stream, where portions of the encoded stream having the same duration are contained in each Cluster element within the Matroska file in accordance with an embodiment of the invention is illustrated in FIG. **5***a*. The Cues element **52'** shown in FIG. **5***a* is similar to the Cues element **52** shown in FIG. **5** with the exception that the CuePoint elements **70'** do not include a CueTime attribute (see **72** in FIG. **5**) and/or the CueTrackPositions elements **74'** do not include a CueTrack attribute (**76** in FIG. **5**). When the portions of encoded media in each Cluster element in the Matroska container file have the same duration, the CueTime attribute is not necessary. When the Matroska contain file includes a single encoded stream, the CueTrack attribute is not necessary. In other embodiments, the Cues element and/or other elements of the Matroska container file can be modified to remove elements and/or attributes that are not necessary for the adaptive bitrate streaming of the encoded stream contained within the Matroska container file, given the manner in which the stream is encoded and inserted in the Matroska container file.

Although various modifications to the Cues element to include information concerning the size of each of the Cluster elements within a Matroska container file and to eliminate unnecessary attributes are described above, many embodiments of the invention utilize a conventional Matroska container. In several embodiments, the playback device simply determines the size of Cluster elements on the fly using information obtained from a conventional Cues element, and/or relies upon a separate index file containing information concerning the size and/or location of the Cluster elements within the MKV container file. In several embodiments, the additional index information is stored in the top level index file. In a number of embodiments, the additional index information is stored in separate files that are identified in the top level index file. When index information utilized to retrieve Cluster elements from a Matroska container file is stored separately from the container file, the Matroska container file is still typically constrained to encode media for inclusion in the Cluster elements in the manner outlined above. In addition, wherever the index information is located, the index information will typically index each Cluster element and include (but not be limited to) information concerning at least the starting location and, in many instances, the size of each Cluster element.

Incorporating Hierarchical Indexes into MKV Containers

Retrieval of media using HTTP during adaptive streaming can be improved by adding additional index information to the Matroska container files used to contain each of the encoded streams. In a number of embodiments, the index is a reduced index in that the index only points to the IDRs at the start of each cluster. In many embodiments, the index of the Matroska container file includes additional non-standard attributes (i.e. attributes that do not form part of the Matroska container file format specification) that specify the size of each of the clusters so that a playback device can retrieve a Cluster element from the Matroska container file via HTTP using a byte range request. In several embodiments, the Matroska container file includes a hierarchical index using a HierarchicalIndex element similar to the hierarchical indexes disclosed in U.S. patent application Ser. No. 12/272,631 entitled "Hierarchical and Reduced Index

Structures for Multimedia Files" to Soroushian et al. filed Nov. 17, 2008 to increase the speed with which a playback device can seek to a specific Cluster element containing encoded media within the container file. The disclosure of U.S. patent application Ser. No. 12/272,631 is hereby incorporated by reference in its entirety.

A hierarchical index included in a Matroska container file using a HierarchicalIndex element in accordance with an embodiment of the invention is illustrated in FIG. **7**. The HierarchicalIndex element **54** includes a plurality of HierarchicalIndexPointer elements **80** that each point to a CuePoint element **70** within the Cues element **52**. In this way, the hierarchical index can be utilized to rapidly locate specific Cluster elements within a Matroska file using the Timecode attribute of the Cluster element. Furthermore, the entire index (i.e. the entire Cues element) need not be downloaded in order to locate a specific Cluster element. The playback device can simply download the hierarchical index and download the specific CuePoint elements that enable the location of a desired Cluster element within the Matroska container file.

In several embodiments, the HierarchicalIndex element is generated so that the HierarchicalIndexPointer elements point to CuePoint elements indexing Cluster elements that are a predetermined time period apart. For example, the HierarchicalIndexPointer elements can point to CuePoint elements indexing Cluster elements that are spaced 30 seconds apart. In other implementations, any of a variety of implementations can be utilized to determine the interval between the CuePoint elements referenced by the higher layers of the hierarchical index. In addition, although a two layer hierarchical index is illustrated in FIG. **7**, hierarchical indexes including three or more layers can also be incorporated within Matroska container files generated for use in adaptive bitrate streaming systems in accordance with embodiments of the invention.

As noted above, index information can be stored in a separate file to the Matroska container file in accordance with embodiments of the invention. In embodiments where the index information is stored separately, the index can be hierarchical to prevent the need to download the entire index for a container file prior to playback and to facilitate seeking within the index.

Encoding and Protecting Source Media for Adaptive Bitrate Streaming

A process for encoding source media as a top level index file and a plurality of Matroska container files for use in an adaptive bitrate streaming system in accordance with an embodiment of the invention is illustrated in FIG. **8**. The encoding process **100** commences by writing headers for each of the MKV files that will contain the streams of content generated using the source content. In the illustrated embodiment, the source content includes a stream of video that is encoded as a plurality of protected streams. The frames of the source video are encoded (**104**) using the encoding parameters associated with each of the alternative streams and portions of the encoded frames can be encrypted using a frame key selected from a set of frame keys. When the encoding and encryption of the streams is complete, an index is inserted (**106**) into each Matroska container file containing an alternative stream of protected video. The common set of frame keys is also encrypted (**108**) and the process writes (**110**) a DRM header including the encrypted set of frame keys to each container file. DRM headers and processes for restricting access to cryptographic information stored within the DRM header of a Matroska container file in accordance with embodiments of the invention are discussed further below.

A process for encoding and protecting frames of video to create a plurality of alternative streams of protected video in accordance with embodiments of the invention is illustrated in FIG. **9**. The process **120** includes selecting (**122**) a first portion of the source media and encoding (**123**) the source media using the encoding parameters for each alternative stream. Assuming that the resulting frame is to be encrypted, a frame key can be selected (**124**) from a common set of frame keys and utilized to encrypt at least a portion of the frame of video. A DRM Info element can then be written (**125**) to a BlockGroup element. The DRMInfo element identifies the portion of the frame that is encrypted and the frame key that can be utilized by a playback device to access the encrypted portion of the frame. The encoded and/or encrypted frame can then be written (**126**) to the BlockGroup element. When the entire source video stream is determined (**127**) as being encoded and protected, then the process is complete.

Each portion of source video that is encoded (**123**) can be encoded as a single GOP commencing with an IDR frame. In many embodiments, encoding parameters used to create the alternative GOPs vary based upon bitrate, frame rate, encoding parameters and resolution. In this way, the portion of media is encoded as a set of interchangeable alternatives and a playback device can select the alternative most appropriate to the streaming conditions experienced by the playback device. When different resolutions are supported, the encoding of the streams is constrained so that each stream has the same display aspect ratio. A constant display aspect ratio can be achieved across different resolution streams by varying the sample aspect ratio with the resolution of the stream. In many instances, reducing resolution can result in higher quality video compared with higher resolution video encoded at the same bit rate.

Although specific processes involving the encoding and protection of a source video stream as a set of alternative streams are illustrated in FIGS. **8** and **9**, any of a variety of processes can be utilized to protect audio, video, and/or subtitle streams using common cryptographic information in accordance with embodiments of the invention. Following the encoding of the source media to create Matroska container files containing each of the protected streams, which can include trick play streams, the Matroska container files can be uploaded to a content distribution server for adaptive bitrate streaming to playback devices. The adaptive bitrate streaming of protected media encoded in accordance with embodiments of the invention using HTTP requests is discussed further below.

DRM Headers

Common cryptographic information utilized in protecting alternative streams can be inserted into container files containing each of the alternative streams. When the container files are Matroska container files, the common cryptographic information can be inserted into the container file as a DRMHeader element. A DRMHeader element configured to contain a set of keys in accordance with an embodiment of the invention is illustrated in FIG. **10**. The DRM Header element **130** includes a plurality of pieces of information **132** including a frame keys record **134** that can be utilized to contain a set of frame keys or frame key table common to each of a plurality of alternative streams.

If the frame key record **134** is communicated in the clear, then any playback device can access the protected streams. Therefore, the frame keys record **134** is typically encrypted

using one or more encryption keys. The encryption key(s) used to encrypt the frame key record **134** can be securely provided to an individual playback device using any of a variety of techniques appropriate to a specific application. In the context of streaming systems that also support the downloading of content.

Although a specific format for storing common cryptographic information in a Matroska container file is illustrated in FIG. **10**, any format can be utilized to store common cryptographic information in a Matroska container file and/or any other container file appropriate to a specific application in accordance with an embodiment of the invention. Adaptive bitrate streaming of protected content in accordance with embodiments of the invention is discussed further below.

Adaptive Bitrate Streaming from MKV Container Files Using HTTP

When source media is encoded so that there are alternative streams of protected media contained in separate Matroska container files for at least one of video, audio, and subtitle content, adaptive streaming of the media contained within the Matroska container files can be achieved using HTTP requests or a similar stateless data transfer protocol. In many embodiments, a playback device requests a top level index file from a content distribution server and uses the index information to identify the streams that are available to the playback device and the cryptographic information required to access any protected streams. The playback device can then retrieve the indexes for one or more of the Matroska files and can use the indexes to request media from one or more of the protected streams contained within the Matroska container files using HTTP requests or using a similar stateless protocol. As noted above, many embodiment of the invention implement the indexes for each of the Matroska container files using a modified Cues element. In several embodiments, the index is a hierarchical index and is also includes a HierarchicalIndex element contained within the Matroska container file. In a number of embodiments, however, the encoded media for each stream is contained within a standard Matroska container file and separate index file(s) can also be provided for each of the container files.

Based upon the streaming conditions experienced by the playback device, the playback device can select media from alternative protected streams encoded at different bitrates. When the media from each of the streams is protected using common cryptographic information and inserted into the Matroska container files in the manner outlined above, transitions between streams can occur upon the completion of playback of media within a Cluster element without the need to retrieve additional cryptographic information. As noted above, the size of the Cluster elements (i.e. the duration of the encoded media within the Cluster elements) is typically chosen so that the playback device is able to respond quickly enough to changing streaming conditions and to instructions from the user that involve utilization of a trick play track. The smaller the Cluster elements (i.e. the smaller the duration of the encoded media within each Cluster element) the higher the overhead associated with requesting each Cluster element. Therefore, a tradeoff exists between the responsiveness of the playback device to changes in streaming conditions and the effective data rate of the adaptive streaming system for a given set of streaming conditions (i.e. the portion of the available bandwidth actually utilized to transmit encoded media). In many embodiments, the size of the Cluster elements is chosen so that each Cluster element contains two seconds of encoded media. In other embodiments, the duration of the encoded media can be greater or less than two seconds and/or the duration of the encoded media can vary from Cluster element to Cluster element.

Communication between a playback device or client and an HTTP server during the playback of media encoded in separate streams contained within Matroska container files indexed by a top level index file in accordance with an embodiment of the invention is illustrated in FIG. **11**. In the illustrated embodiment, the playback device **200** commences playback by requesting the top level index file from the server **202** using an HTTP request or a similar protocol for retrieving data. The server **202** provides the bytes corresponding to the request. The playback device **200** then parses the top level index file to identify the URIs of each of the Matroska container files containing the streams of encoded media derived from a specific piece of source media. The playback device can then request the byte ranges corresponding to headers of one or more of the Matroska container files via HTTP or a similar protocol, where the byte ranges are determined using the information contained in the URI for the relevant Matroska container files (see discussion above). The server returns the following information in response to a request for the byte range containing the headers of a Matroska container file:

ELEM("EBML")
ELEM("SEEKHEAD")
ELEM("SEGMENTINFO")
ELEM("TRACKS")

The EBML element is typically processed by the playback device to ensure that the file version is supported. The SeekHead element is parsed to find the location of the Matroska index elements and the SegmentInfo element contains two key elements utilized in playback: TimecodeScale and Duration. The TimecodeScale specifies the timecode scale for all timecodes within the Segment of the Matroska container file and the Duration specifies the duration of the Segment based upon the TimecodeScale. The Tracks element contains the information used by the playback device to decode the encoded media contained within the Clusters element of the Matroska file including the common cryptographic information, which can take a variety of forms including but not limited to a DRMHeader element. As noted above, adaptive bitrate streaming systems in accordance with embodiments of the invention can support different streams encoded using different encoding parameters including but not limited to frame rate, and resolution. Therefore, the playback device can use the information contained within the Matroska container file's headers to configure the decoder every time a transition is made between encoded streams. Due to the fact that alternative protected streams utilize the same cryptographic information, the engine utilized to decrypt the content on the client **200** (i.e. the software process used to decrypt encrypted portions of frames of video) does not require reconfiguration using different cryptographic information with each stream switch.

In many embodiments, the playback device does not retrieve the headers for all of the Matroska container files indexed in the top level index file. Instead, the playback device determines the stream(s) that will be utilized to initially commence playback and requests the headers from the corresponding Matroska container files. Depending upon the structure of the URIs contained within the top level index file, the playback device can either use information from the URIs or information from the headers of the Matroska container files to request byte ranges from the server that

contain at least a portion of the index from relevant Matroska container files. The byte ranges can correspond to the entire index or can correspond to the top level of a hierarchical index and a portion of a lower level index (i.e. a HierarchicalIndex element and one or more CuePoint elements). The server provides the relevant byte ranges containing the index information to the playback device, and the playback device can use the index information to request the byte ranges of Cluster elements containing encoded media using this information. When the Cluster elements are received, the playback device can extract encoded media from the BlockGroup elements within the Cluster element, and can decode and playback the media within the BlockGroup elements in accordance with their associated Timecode attributes. Prior to decoding the encoded media, the playback device can check for the presence of a DRMInfo element within each BlockGroup of a video stream to identify whether the encoded media is protected. The playback device can use the information within the DRMInfo element to decrypt encrypted portions of the video prior to decoding.

In the illustrated embodiment, the playback device **200** requests sufficient index information from the HTTP server prior to the commencement of playback that the playback device can stream the entirety of each of the selected streams using the index information. In other embodiments, the playback device continuously retrieves index information as media is played back. In several embodiments, all of the index information for the lowest bitrate steam is requested prior to playback so that the index information for the lowest bitrate stream is available to the playback device in the event that streaming conditions deteriorate rapidly during playback.

Switching Between Streams

The communications illustrated in FIG. **11** assume that the playback device continues to request media from the same streams (i.e. Matroska container files) throughout playback of the media. In reality, the streaming conditions experienced by the playback device are likely to change during the playback of the streaming media and the playback device can request media from alternative streams (i.e. different Matroska container files) to provide the best picture quality for the streaming conditions experienced by the playback device. In addition, the playback device may switch streams in order to perform a trick play function that utilizes a trick play track stream.

Communication between a playback device and a server when a playback device switches to a new stream in accordance with embodiments of the invention are illustrated in FIG. **12***a*. The communications illustrated in FIG. **12***a* assume that the index information for the new stream has not been previously requested by the playback device and that downloading of Cluster elements from the old stream proceeds while information is obtained concerning the Matroska container file containing the new stream. When the playback device **200** detects a change in streaming conditions, determines that a higher bitrate stream can be utilized at the present streaming conditions, or receives a trick play instruction from a user, the playback device can use the top level index file to identify the URI for a more appropriate alternative stream to at least one of the video, audio, or subtitle streams from which the playback device is currently requesting encoded media. The playback device can save the information concerning the current stream(s) and can request the byte ranges of the headers for the Matroska container file(s) containing the new stream(s) using the parameters of the corresponding URIs. Caching the information in this way can be beneficial when the playback device attempts to adapt the bitrate of the stream downward. When the playback device experiences a reduction in available bandwidth, the playback device ideally will quickly switch to a lower bitrate stream. Due to the reduced bandwidth experienced by the playback device, the playback device is unlikely to have additional bandwidth to request header and index information. Ideally, the playback device utilizes all available bandwidth to download already requested higher rate Cluster elements and uses locally cached index information to start requesting Cluster elements from Matroska container file(s) containing lower bitrate stream(s). When a hierarchical index is used, the playback device typically will download additional index information. However, the amount of index information that is downloaded is significantly reduced as the headers of the Matroska container file are already cached on the playback device and the playback device only needs a portion of the index in order commence requesting Cluster elements from the Matroska container file(s) containing the new stream(s).

Byte ranges for index information for the Matroska container file(s) containing the new stream(s) can be requested from the HTTP server **202** in a manner similar to that outlined above with respect to FIG. **11**. At which point, the playback device can stop downloading of cluster elements from the previous streams and can commence requesting the byte ranges of the appropriate Cluster elements from the Matroska container file(s) containing the new stream(s) from the HTTP server, using the index information from the Matroska container file(s) to identify the Cluster element(s) containing the encoded media following the encoded media in the last Cluster element retrieved by the playback device. As noted above, the encoding of the alternative streams so that corresponding Cluster elements within alternative streams (i.e. Cluster elements containing the same portion of the source media encoded in accordance with different encoding parameters) start with the same Timecode element and an IDR frame facilitates the smooth transition from one stream to another. In addition, the use of common cryptographic information further facilitates smooth switching between alternative streams.

When the Matroska file includes a hierarchical index, the process for switching between streams can involve downloading less than the entire index of the new streams. The index information can be downloaded by requesting the byte range for the hierarchical index and then using the Timecode attribute of media played back by the playback device **200** to identify the location of CuePoint elements within the Matroska container file(s) containing the new stream(s) that reference Cluster elements containing sequential encoded media and requesting the byte ranges of the CuePoint elements from the HTTP server **202**. After the HTTP server has provided the byte ranges including the CuePoint elements, the playback device can use the information within the CuePoint elements to request byte ranges containing desired Cluster elements from the HTTP server. At which point, playback of the encoded media contained within the Cluster elements proceeds in the manner discussed above.

When the playback device caches the header and the entire index for each stream that has be utilized in the playback of the media, the process of switching back to a previously used stream can be simplified. The playback device already has the header and index information for the Matroska file containing the previously utilized stream and the playback device can simply use this information to start requesting Cluster elements from the Matroska container file of the previously utilized stream via HTTP. Communication

between a playback device and an HTTP server when switching back to a stream(s) for which the playback device has cached header and index information in accordance with an embodiment of the invention is illustrated in FIG. **12***b*. The process illustrated in FIG. **12***b* is ideally performed when adapting bitrate downwards, because a reduction in available resources can be exacerbated by a need to download index information in addition to media. The likelihood of interruption to playback is reduced by increasing the speed with which the playback device can switch between streams and reducing the amount of overhead data downloaded to achieve the switch. When a hierarchical index is utilized, the playback device requests the appropriate portion of the index from the Matroska container file(s) containing the lower bitrate stream(s) prior to requesting Cluster elements from the Matroska container file.

Although the present invention has been described in certain specific aspects, many additional modifications and variations would be apparent to those skilled in the art. It is therefore to be understood that the present invention may be practiced otherwise than specifically described, including various changes in the implementation such as utilizing encoders and decoders that support features beyond those specified within a particular standard with which they comply, without departing from the scope and spirit of the present invention. Thus, embodiments of the present invention should be considered in all respects as illustrative and not restrictive.

What is claimed:

1. A playback device for playing protected content from a plurality of alternative streams, comprising:

a set of one or more processors; and

a non-volatile storage containing an application for causing the set of one or more processors to perform the steps of:

obtaining a top level index file identifying a plurality of alternative streams of protected video, wherein each of the alternative streams of protected video includes partially encrypted video frames that are encrypted using a set of common keys comprising at least one key, and wherein the partially encrypted video frames contain encrypted portions and unencrypted portions of data;

obtaining a copy of the set of common keys;

detecting streaming conditions for the playback device;

selecting a stream from the plurality of alternative streams of protected video based on the detected streaming conditions;

receiving a container index that provides byte ranges for portions of the selected stream of protected video within an associated container file;

requesting portions of the selected stream of protected video based on the provided byte ranges;

locating encryption information that identifies encrypted portions of frames of video within the requested portions of the selected stream of protected video;

decrypting each encrypted portion of the frames of video identified within the located encryption information using the set of common keys; and

playing back the decrypted frames of video obtained from the requested portions of the selected stream of protected video.

2. The playback device of claim **1**, wherein the step of requesting portions of the selected stream further comprises the step of obtaining a container file containing protected video from at least one of the plurality of alternative streams, where the container file also includes encryption information that identifies portions of frames of video that are encrypted and a reference to at least one key from the set of common keys to utilize in accessing the encrypted portions of the frames of video.

3. The playback device of claim **1**, wherein the located encryption information comprises a reference to the start of an encrypted block of data.

4. The playback device of claim **3**, wherein the located encryption information further comprises the size of the encrypted block of data.

5. The playback device of claim **3**, wherein the located encryption information further comprises cryptographic information that can be utilized to access the encrypted portion of the frame.

6. The playback device of claim **5**, wherein the cryptographic information is a reference to at least one key from the set of common keys.

7. The playback device of claim **1**, wherein the application is further for causing the set of processors to perform the steps of:

detecting a change in the streaming conditions;

identifying a second alternative stream of protected video based on the detected change;

receiving a container index that provides byte ranges for portions of the second alternative stream of protected video within a second associated container file;

requesting portions of the second alternative stream of protected video based on the provided byte ranges;

decrypting each encrypted portion of the frames of video from the requested portions of the second alternative stream of protected video using the set of common keys; and

playing back the decrypted frames of video from the requested portions of the second alternative stream of protected video.

8. The playback device of claim **1**, wherein the application is further for causing the set of processors to perform the steps of:

transmitting a request for content to a set of one or more content distribution servers; and

receiving the content from the set of one or more content distribution servers.

9. The playback device of claim **8**, wherein the application is further for causing the set of processors to perform the steps of:

transmitting a request for cryptographic information including the set of common keys to a set of one or more DRM servers; and

receiving the cryptographic information from the set of one or more DRM servers.

10. The playback device of claim **1**, wherein the application is further for causing the set of processors to perform the step of obtaining the container index from at least one file selected from the group consisting of: the associated container file containing the selected stream of protected content; and a separate file to the associated container file containing the selected stream of protected content.

11. The playback device of claim **1**, wherein the common set of keys comprises a plurality of keys.

12. A method for playing protected content from a plurality of alternative streams on a playback device, the method comprising:

obtaining a top level index file identifying a plurality of alternative streams of protected video, wherein each of the alternative streams of protected video includes partially encrypted video frames that are encrypted

using a set of common keys comprising at least one key, and wherein the partially encrypted video frames contain encrypted portions and unencrypted portions of data;

obtaining a copy of the set of common keys;

detecting streaming conditions for the playback device;

selecting a stream from the plurality of alternative streams of protected video based on the detected streaming conditions;

receiving a container index that provides byte ranges for portions of the selected stream of protected video within an associated container file;

requesting portions of the selected stream of protected video based on the provided byte ranges;

locating encryption information that identifies encrypted portions of frames of video within the requested portions of the selected stream of protected video;

decrypting each encrypted portion of the frames of video identified within the located encryption information using the set of common keys; and

playing back the decrypted frames of video obtained from the requested portions of the selected stream of protected video using a decoder.

13. The method of claim **12**, wherein requesting portions of the selected stream further comprises obtaining a container file containing protected video from at least one of the plurality of alternative streams, where the container file also includes encryption information that identifies portions of frames of video that are encrypted and a reference to at least one key from the set of common keys to utilize in accessing the encrypted portions of the frames of video.

14. The method of claim **12**, wherein the located encryption information comprises a reference to the start of an encrypted block of data.

15. The method of claim **14**, wherein the located encryption information further comprises the size of the encrypted block of data.

16. The method of claim **14**, wherein the located encryption information further comprises cryptographic information that can be utilized to access the encrypted portion of the frame.

17. The method of claim **16**, wherein the cryptographic information is a reference to at least one key from the set of common keys.

18. The method of claim **12** further comprising:

detecting a change in the streaming conditions;

identifying a second alternative stream of protected video based on the detected change;

receiving a container index that provides byte ranges for portions of the second alternative stream of protected video within a second associated container file;

requesting portions of the second alternative stream of protected video based on the provided byte ranges;

decrypting each encrypted portion of the frames of video from the requested portions of the second alternative stream of protected video using the set of common keys; and

playing back the decrypted frames of video from the requested portions of the second alternative stream of protected video.

19. The method of claim **12** further comprising:

transmitting a request for content to a set of one or more content distribution servers; and

receiving the content from the set of one or more content distribution servers.

20. The method of claim **19** further comprising:

transmitting a request for cryptographic information including the set of common keys to a set of one or more DRM servers; and

receiving the cryptographic information from the set of one or more DRM servers.

21. The method of claim **12** further comprising obtaining the container index from at least one file selected from the group consisting of: the associated container file containing the selected stream of protected content; and a separate file to the associated container file containing the selected stream of protected content.

22. The method of claim **12**, wherein the common set of keys comprises a plurality of keys.

23. The playback device of claim **1**, wherein:

the container index is part of a hierarchical index; and

the application is further for causing the set of processors to perform the step of:

obtaining a lower layer index that identifies the location of frames within a specific requested portion of the selected stream of protected video; and

identify partially encrypted video frames from within the specific requested portion of the selected stream using the lower layer index.

24. The method of claim **12**, wherein:

the container index is part of a hierarchical index; and

the method further comprises:

obtaining a lower layer index that identifies the location of frames within a specific requested portion of the selected stream of protected video; and identify partially encrypted video frames from within the specific requested portion of the selected stream using the lower layer index.

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