TRANSMISSION OF RECONSTRUCTION DATA IN A TIERED SIGNAL QUALITY HIERARCHY

BACKGROUND

Today the majority of Internet traffic is made of video content, most of which transmitted through video streaming. At the same time, most TV contents are now broadcasted using digital video transmission.

However, conventional video codecs (e.g., MPEG family codecs or other frequency-transform based / block-based codecs) were not developed with video streaming in mind, since at the time in which they were developed the Internet was still in its infancy and the bandwidth available didn't allow for effective video streaming.

As a consequence, when video streaming functionalities were added, the main algorithms and formats were already defined, and didn't allow for features that are important in the context of video transmission through digital channels that may present variable/unpredictable bitrates and variable/unpredictable noise.

For instance, current algorithms and bitstream formats don't allow streaming servers – starting from a single encoded file – to dynamically adapt the level of quality of a video stream to the characteristics of the specific decoder / display device at the receiving end: if a signal is encoded in high quality, it must be transmitted in full resolution (with notable use of bandwidth and computing resources at the decoding end) even when the receiving end possesses a low-resolution display device (e.g., mobile phone, tablet, etc.).

In the same way, it isn't possible to dynamically adapt the level of quality of the video stream to the bandwidth available (e.g., in cases of network congestion or limited available bandwidth), or to the level of service requested by the decoder device (e.g., pay-per-view services dependent on the level of quality of the stream).

Another limitation is that in case of errors in transmission due to noisy channels, very visible "blocky" artifacts appear (as a consequence of the fact that information pertaining entire blocks of the signal may have been corrupted), with no possibility for the more graceful signal degradation that was typical of analog transmissions.

Also, it isn't possible to allow the decoder to browse (e.g., fast forward) through a low

quality version of the video stream before having finished downloading / buffering the whole stream, with the consequence that the decoder device will have to download also segments of the signal that will be never played back (with consequent waste of time and bandwidth).

In addition, current algorithms and transmission formats aren't engineered for best usage of the available bandwidth in the case of constant bit rates (CBR), with the consequence that they must encode the signal so that the images that contain the most information don't exceed the constant bit rate (with consequent lower usage of the CBR for all of the other images).

Lastly, traditional MPEG family codecs are structurally non-parallel. This stems from the fact that they are block-based, and each image block must be encoded and decoded sequentially, since to achieve efficient compression, all blocks must be made to depend in some way on each other. As a consequence, also the bitstream is not organized so as to allow for parallel decoding by many independent computing cores/devices.

Such limitations are true for video streaming (2D or multiview), but also carry over to other areas of application that are becoming increasingly important, such as the efficient transmission of 3D or volumetric imaging, which is becoming more and more important in fields such as medical imaging, scientific imaging, etc.

BRIEF DESCRIPTION

Embodiments herein deviate with respect to conventional systems and methods. For example, embodiments herein are directed to unique ways of using reconstruction data to reconstruct renditions of a signal at one or more different levels of quality.

More specifically, one embodiment herein includes a method comprising:

retrieving reconstruction data and metadata, the retrieved reconstruction data and metadata being a subset of available data selected from a repository for distribution to a decoder, the retrieved reconstruction data encoded in accordance with a tiered hierarchy including multiple available levels of quality in which portions of a signal are encoded;

transmitting the retrieved reconstruction data to a decoder, the decoder configured to reconstruct renditions of the signal based on the transmitted reconstruction data; and

during the transmission, varying a level of quality of the reconstruction data retrieved and transmitted to the decoder.

Another embodiment includes computer-readable storage hardware having instructions stored thereon, the instructions, when carried out by a processing device, causing the processing device to perform operations of:

retrieving reconstruction data from a repository, the retrieved reconstruction data encoded in accordance with a tiered hierarchy including multiple available levels of quality in which portions of a signal are encoded;

transmitting the retrieved reconstruction data to a decoder, the decoder configured to reconstruct renditions of a signal based on the transmitted reconstruction data; and

during the transmission, varying a level of quality of the reconstruction data retrieved from the tiered hierarchy and transmitted to the decoder.

Yet a further embodiment includes a computer system comprising:

a processor including processing hardware;

a hardware storage unit that stores instructions associated with an application executed by the processor; and

an interconnect coupling the processor and the hardware storage unit, causing the processing hardware to execute the application and perform operations of:

retrieving reconstruction data from a repository, the retrieved reconstruction data encoded in accordance with a tiered hierarchy including multiple available levels of quality in which portions of the signal are encoded;

transmitting the retrieved reconstruction data to a decoder, the decoder configured to reconstruct renditions of the signal based on the transmitted reconstruction data; and

during the transmission, varying a level of quality of the reconstruction data retrieved from the tiered hierarchy and transmitted to the decoder.

Also disclosed herein is a signal processor configured to retrieve reconstruction data from a repository. The reconstruction data is encoded in accordance with a tiered hierarchy including multiple levels of quality. The signal processor transmits selected portions of the reconstruction data to a decoder resource. The decoder resource reconstructs renditions of a signal based on the transmitted portions of reconstruction data. During the step of

transmitting, the signal processor retrieving the reconstruction data from the repository varies a level of quality of the reconstruction data

transmitted to the decoder resource. The decoder resource decodes the received reconstruction data to play back the signal at different levels of quality. Thus, signal can be encoded to include appropriate reconstruction data to reconstruct each frame of the signal at a highest level of quality. However, the signal processor can be configured to selectively transmit portions of the reconstruction data to a remote resource such as a decoder.

In one embodiment, varying the level of quality of reconstruction data transmitted to the decoder resource can include: transmitting a first set of reconstruction data to the decoder resource for play back of a first portion of the signal and transmitting a second set of reconstruction data to the decoder resource for play back of a second portion of the signal. The first set of reconstruction data (e.g., X tiers of reconstruction data) indicates how to reconstruct a rendition of the first portion of the signal in accordance with a first level of quality in the tiered hierarchy. The second set of reconstruction data (e.g., Y tiers of reconstruction data) indicates how to reconstruct a rendition of the second portion of the signal in accordance with a second level of quality in the tiered hierarchy. When $X > Y$, the first level of quality is greater than the second level of quality; when $Y > X$, the opposite is true.

The tiers of reconstruction data can be transmitted at different levels of quality for a number of different reasons. For example, the second set of reconstruction data may be transmitted from the signal processor to a decoder resource at the second level of quality instead of the first level of quality in response to detecting an inability to transmit, due to network congestion, the second set of reconstruction data according to the first level of quality. In accordance with such an embodiment, the reconstruction data to reconstruct the first portion of the signal can include X levels of quality of reconstruction data; the reconstruction data to reconstruct the second portion of the signal can include Y levels of quality of reconstruction data. Reducing an amount of transmitted data (e.g., reconstruction data) enables a decoder to reconstruct at least a lower level of quality version of the signal.

In one embodiment, the signal processor varies the level of quality of the reconstruction data to facilitate playback of the signal in substantially real-time by the decoder resource.

In accordance with another embodiment, the signal processor can be configured to transmit the second set of reconstruction data at the second level of quality in response to receiving

a request to transmit the second set of reconstruction data at the second level of quality instead of the first level of quality. For example, a source such as the decoder resource can request transmission of the signal in accordance with a higher or lower quality than a previously transmitted frame or sets of frames. In response to the request, the decoder resource transmits the reconstruction data at the requested level of quality.

In one embodiment, the signal processor varies a highest level of quality of reconstruction data transmitted to the decoder resource for each of multiple frames of the signal in order to transmit a substantially constant bit rate of tiered reconstruction data to the decoder resource for each of multiple successive frames of the signal. Thus, the level of quality of reconstruction data transmitted to a decoder can be varied in order to produce a substantially constant bit rate data stream.

Reconstruction data for frames of the signal can be transmitted according to a different level of quality depending on the level of reconstruction data retrieved from the repository and forwarded from the signal processor to the decoder resource. For example, in one embodiment, varying the level of quality of reconstruction data can include: i) for a first portion of the signal, retrieving reconstruction data from the repository and producing a first set of reconstruction data to include a sequence of reconstruction data from a lowest level of quality in the hierarchy up to a first level of quality; and ii) for a second portion of the signal, retrieving reconstruction data from the repository and producing a second set of reconstruction data to include a sequence of reconstruction data from the lowest level of quality in the hierarchy up to a second level of quality. As mentioned, the second level of quality can be higher or lower than first level of quality. The signal processor transmits the first set of reconstruction data to the decoder resource for play back of the first portion of the signal in accordance with the first level of quality; the signal processor transmits the second set of reconstruction data to the decoder resource for play back of the second portion of the signal in accordance with the second level of quality.

In accordance with further embodiments, the signal processor can be configured to transmit the lower levels of quality of reconstruction data for each of multiple portions of the signal followed by transmission of higher levels of quality of reconstruction data. For example, the signal processor can be configured to produce a first set of reconstruction data to

include reconstruction data to reconstruct multiple portions of the signal in accordance with a first level of quality in the hierarchy. The signal processor transmits the first set of reconstruction data to the decoder resource to enable navigation amongst the signal in accordance with the first level of quality. In one embodiment, transmission of the first set of reconstruction data can be achieved in relatively little time because the first set of reconstruction data enables reconstruction according to a low level of quality. The decoder resource can initiate playback of the first set of reconstruction data enabling a respective user to quickly navigate (e.g., via commands such as fast forward, reverse, etc.) amongst playback of a low-resolution (e.g., lower level of quality) version of the signal. Based on viewing the low-resolution signal, the user can select a pointer value indicating a location in the signal for playback at a higher level of quality.

In response to the selection of a particular location in the low-resolution data stream, the signal processor produces a second set of reconstruction data (potentially starting from the requested location as by the pointer value) to include reconstruction data to reconstruct the signal in accordance with a second level of quality in the hierarchy. The signal processor transmits the second set of reconstruction data to the decoder resource for play back of the second portion of the signal in accordance with the higher level of quality.

A combination of the first set of reconstruction data (initial transmission) and second set of reconstruction data (subsequent transmission) enable playback of the signal in accordance with the second level of quality. More specifically, based on the navigation example as discussed above, the second set of reconstruction data (e.g., reconstruction data to reconstruct the signal at the higher level of quality) is supplemental reconstruction data with respect to the first set of reconstruction data. The second set of reconstruction data indicates how to modify a rendition of the signal generated based on the first set of reconstruction data in order to reconstruct portions of the signal following the pointer value according to the second level of quality.

In accordance with further embodiments, the reconstruction data can be distributed based on a fee schedule in which a respective user operating the decoder resource is charged a different amount of money or fee depending on a level of quality of the reconstruction data transmitted to the decoder resource. The user can initially receive reconstruction data

according to a first level of quality and subsequently request transmission of the additional reconstruction data to playback content according to a second, higher level of quality.

In accordance with further embodiments, note that portions of the reconstruction data can be protected via application of digital rights management with respect to a selected portion of the reconstruction data. For example, as mentioned, each portion (e.g., image, frame, portion, etc.) of the signal can be defined by a respective tiered set of reconstruction data to reconstruct a rendition of the signal. Decoding with higher tiers of the reconstruction data enables playback of the signal at a higher level of quality. Embodiments herein include implementing digital rights management with respect to only lower tiers of the sets of reconstruction data (e.g., the lower level of quality reconstruction data). In accordance with such an embodiment, this prevents unauthorized decoding of the reconstruction data at the lower level of quality. Higher tiers of the reconstruction data are accessible and may not be protected by digital rights management. However, without the ability to decode the lower level of quality reconstruction data because they are protected via digital rights management, an unauthorized decoder resource is unable to use the higher level of quality reconstruction data to produce a meaningful rendition of the signal. In other words, use of the higher level of quality reconstruction data is dependent on successful decoding of corresponding lower level of quality reconstruction data, which is protected by digital rights management.

In accordance with another embodiment, the signal processor can generate the sets of reconstruction data at one or more levels of quality to include redundant encoding to enable playback of the signal. The reconstruction data at the low level of quality can include redundant encoding to enable playback of the lower level of quality reconstruction data in the event of an error. The signal processor generates higher level of quality reconstruction data to include non-redundant encoding. Accordingly, a user receiving the reconstruction data more likely will be able to playback the signal at least at the lower level of quality in the event of an error as the higher level of quality reconstruction data may be corrupt.

In accordance with yet further embodiments, the signal processor can be configured to parse the reconstruction data into groupings. In one embodiment, each of the groupings of reconstruction data represents a time-based portion (e.g., image, frame, segment, piece,

etc.) of the signal. Each of the groupings of reconstruction data can include multiple sequences of hierarchically tiered reconstruction data from a lowest level of quality to a higher level of quality in the hierarchy. In accordance with such an embodiment, each of the multiple sequences of tiered reconstruction data from a lowest level of quality to the higher level of quality indicates settings of a respective tile of contiguous elements associated with the signal.

Transmission of the reconstruction data to the decoder resource can include serially transmitting each of the multiple sequences in sequential order, one after another, in a bit stream to the decoder, and providing marker information in the bit stream to indicate a respective beginning and end of each tile for each sequence of tiered reconstruction data. The decoder resource can include multiple processors, each of which is configured to decode one of the multiple sequences to produce a tile of the reconstruction data. A combination of tiles produces the reconstruction data used to obtain the rendition of the signal at a higher level of quality.

Alternatively, transmission of the reconstruction data for a portion of the signal can include transmitting the tiered reconstruction data in a bit stream starting from reconstruction data at the lower levels of quality to reconstruction data for the higher level of quality for the multiple sequences associated with a portion of the signal. The signal processor can provide marker information in the bit stream to indicate a respective beginning and end of tiered reconstruction data for each level of quality.

The signal processor can be configured to transmit the reconstruction data for a given portion of the signal over multiple portions of a data stream. For example, in one embodiment, the signal processor partitions a data stream for sending the reconstruction data into multiple segments including at least a first segment and second segment. The first segment of the data stream includes reconstruction data to playback a first image/frame of the signal; the second segment of the data stream includes reconstruction data to playback a second image/frame of the signal.

In one embodiment, the signal processor populates the first segment of the data stream to include multiple levels of quality of reconstruction data to reconstruct the first image/frame of the signal; the signal processor populates the second segment of the data stream to

include: i) multiple levels of quality of reconstruction data to reconstruct the second image/frame of the signal, and ii) at least one level of quality of reconstruction data to reconstruct the first image/frame of the signal. Thus, instead of transmitting reconstruction data for a respective portion of the signal in a corresponding segment of the data stream dedicated for that portion, the reconstruction data for a portion of the signal can be spread out over multiple segments of the data stream.

The decoder resource can be configured to buffer the data stream transmitted by the signal processor. For example, the decoder reconstructs the first image/frame of the signal based on the multiple levels of quality of reconstruction data in the first segment of the data stream and the reconstruction data in the second segment (and potentially also in additional further segments) of the data stream. The signal processor reconstructs the second image/frame of the signal based on the multiple levels of quality of reconstruction data in the second segment. In this manner, the higher level of quality reconstruction data can be spread out in a respective data stream.

These and other embodiment variations are discussed in more detail below.

As mentioned above, note that embodiments herein can include a configuration of one or more computerized devices, routers, network, workstations, handheld or laptop computers, or the like to carry out and/or support any or all of the method operations disclosed herein. In other words, one or more computerized devices or processors can be programmed and/or configured to operate as explained herein to carry out different embodiments.

In addition to the upsampling as discussed above, yet other embodiments herein include software programs to perform the steps and operations summarized above and disclosed in detail below. One such embodiment comprises a computer-readable, hardware storage resource (i.e., a non-transitory computer readable media) including computer program logic, instructions, etc., encoded thereon that, when performed in a computerized device having a processor and corresponding memory, programs and/or causes the processor to perform any of the operations disclosed herein. Such arrangements can be provided as software, code, and/or other data (e.g., data structures) arranged or encoded on a computer readable medium such as an optical medium (e.g., CD-ROM), floppy or hard disk or other a medium such as firmware or microcode in one or more ROM or RAM or PROM chips or

as an Application Specific Integrated Circuit (ASIC). The software or firmware or other such configurations can be installed onto a computerized device to cause the computerized device to perform the techniques explained herein.

Accordingly, one particular embodiment of the present disclosure is directed to a computer program product that includes a computer-readable hardware storage medium having instructions stored thereon for supporting signal processing operations. For example, in one embodiment, the instructions, when carried out by a processor of a respective computer device, cause the processor to: retrieve reconstruction data from a repository, the retrieved reconstruction data encoded in accordance with a tiered hierarchy including multiple levels of quality; transmit the retrieved reconstruction data to a decoder, the decoder configured to reconstruct renditions of a signal based on the transmitted reconstruction data; and during the transmitting, vary a level of quality of the reconstruction data retrieved and transmitted to the decoder.

The ordering of the steps has been added for clarity sake. These steps can be performed in any suitable order.

Other embodiments of the present disclosure include software programs, firmware, and/or respective hardware to perform any of the method embodiment steps and operations summarized above and disclosed in detail below.

Also, it is to be understood that the system, method, apparatus, instructions on computer readable storage media, etc., as discussed herein can be embodied strictly as a software program, as a hybrid of software, firmware, and/or hardware, or as hardware alone such as within a processor, or within an operating system or within a software application, etc.

As discussed above, techniques herein are well suited for use in software, firmware, and/or hardware applications that encode signals. However, it should be noted that embodiments herein are not limited to use in such applications and that the techniques discussed herein are well suited for other applications as well.

Additionally, note that although each of the different features, techniques, configurations, etc., herein may be discussed in different places of this disclosure, it is intended that each of the concepts can be executed independently of each other or in combination with each other. Accordingly, the one or more present inventions, embodiments, etc., as described

herein can be embodied and viewed in many different ways.

Also, note that this preliminary discussion of embodiments herein does not specify every embodiment and/or incrementally novel aspect of the present disclosure or claimed invention(s). Instead, this brief description only presents general embodiments and corresponding points of novelty over conventional techniques. For additional details and/or possible perspectives (permutations) of the invention(s), the reader is directed to the Detailed Description section and corresponding figures of the present disclosure as further discussed below.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, features, and advantages of the invention will be apparent from the following more particular description of preferred embodiments herein, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale, with emphasis instead being placed upon illustrating the embodiments, principles, concepts, etc.

FIG. 1 is an example diagram illustrating generation and use of reconstruction data according to embodiments herein.

FIG. 2 is an example diagram illustrating dividing of parent elements into sub-elements according to embodiments herein.

FIG. 3 is an example diagram illustrating processing, forwarding, and decoding reconstruction data according to embodiments herein.

FIG. 4 is an example diagram illustrating a data stream including different levels of quality of reconstruction data according to embodiments herein.

FIG. 5 is an example diagram illustrating variations in the level of quality of reconstruction data forwarded to a decoder according to embodiments herein.

FIG. 6 is an example diagram illustrating variations in the level of quality of reconstruction data forwarded to a decoder according to embodiments herein.

FIG. 7 is an example diagram illustrating transmission of a group of lower level of quality reconstruction data followed by transmission of higher level of quality reconstruction data according to embodiments herein.

FIG. 8 is an example diagram illustrating a fee structure for distribution of reconstruction data according to embodiments herein.

FIG. 9 is an example diagram illustrating use of digital rights management at one or more lower levels of quality according to embodiments herein.

FIG. 10 is an example diagram illustrating redundancy information for reconstruction data at one or more lower levels of quality according to embodiments herein.

FIGS. 11A and 11B are example diagrams illustrating reconstruction data for each of multiple tiles according to embodiments herein.

FIG. 12 is an example diagram illustrating different ways of reconstruction data for each of multiple tiles according to embodiments herein.

FIG. 13 is an example diagram illustrating buffering of reconstruction data according to embodiments herein.

FIG. 14 is a diagram illustrating an example computer architecture for executing computer code, firmware, software, applications, logic, etc., according to embodiments herein.

FIG. 15 is an example flowchart illustrating a method of utilizing reconstruction data according to embodiments herein.

DETAILED DESCRIPTION

FIG. 1 is an example diagram illustrating generation of reconstruction data according to embodiments herein.

As shown, a signal processor 100-1 downsamples signal 115 into different renditions at lower levels of quality in a hierarchy. In general, downsampling the signal 115 can include producing a rendition of the signal at each of different levels of quality and generating reconstruction data specifying how to convert a given rendition of the signal at a first level of quality into a rendition of the signal at a next higher level of quality in the hierarchy.

Signal processor 100-2 utilizes the reconstruction data 150 to reconstruct renditions of the signal at different levels of quality. The signal processor 100-2 can receive the reconstruction data 150 from any suitable source (e.g., communication link, storage device, etc.).

Note that values associated with the rendition of signal 115 and corresponding rendition of

signal at lower levels of quality can represent any suitable type of data information. By way of non-limiting example, the signal 115 can be audio data, image data (e.g., still or moving, video, images, frames, motion maps, residual data, etc.), symbols, volumetric data, etc., indicating settings of each of multiple signal elements (e.g., pels/plane elements, pixels/picture elements, voxels/volumetric picture elements, etc.) in a respective image, etc. In one embodiment, each of one or more components or elements in the signal 115 can define a respective color setting. In accordance with such an embodiment, color component of an element as specified by the signal data is encoded in accordance with a suitable color space standard such as YUV, RGB, HSV, etc. Reconstruction data 150 specifies how to generate one or more settings for each element in the renditions of signal 115. The reconstruction data 150 can be configured to specify multiple planes of attribute settings.

By way of a non-limiting example, an image represented by signal 115 can be two dimensional (e.g., pictures, video frames, 2D motion maps, etc.), three-dimensional (e.g., 3D/volumetric images, holographic images, CAT-scans, medical/scientific images, 3D motion maps, etc.), or even feature more than three dimensions, a time-based signal (e.g., audio signal, video signal, etc.), and so forth.. When the signal 115 represents a 3-D signal, each element is a volumetric element. For simplicity, embodiments illustrated herein often refer to images that are displayed as 2D planes of settings (e.g., 2D images in a suitable color space), such as for instance a picture. However, the same concepts and methods are also applicable to any other type of signal.

The settings of the signal elements or components indicate how to reconstruct the original signal for playback on a respective playback device. As mentioned, reconstruction data 150 can include multiple planes of reconstruction data 150. Many parameters may be needed to define settings for a given element of signal 115.

In accordance with further embodiments, note that signal 115 can represent an original signal or high-resolution signal including multiple elements. In such an embodiment, each of the renditions of signal (e.g., rendition of signal 115-3, rendition of signal 115-2, rendition of signal 115-1, ...) can be akin to a thumbnail representation of an original signal that has been downsampled from signal 115 to a lower level of quality. Renditions of

signal 115 at higher levels of quality include more detailed playback information.

In one embodiment, the renditions of signal 115 at the lower levels of quality capture coarser attributes of the original signal, but not the more detailed finer attributes of the original signal. The detailed, finer attributes appear in the rendition of signal at higher levels of quality.

By way of further non-limiting example, in one embodiment, the signal processor 100-1 downsamples original signal 115 into rendition of signal 115-3; signal processor 100-1 downsamples rendition of signal 115-3 into rendition of signal 115-2; signal processor 100-1 downsamples rendition of signal 115-2 into rendition of signal 115-1; and so on to a lowest level of quality. The signal 115 can be downsampled into any number of suitable levels from a highest level of quality.

As mentioned, when downsampling the rendition of signal 115 to each lower level of quality, the signal processor 110-1 generates respective reconstruction data 150. Reconstruction data at each level indicates how to upsample, convert, modify, etc., a rendition of signal at a lower level of quality into a rendition of signal at a next higher level of quality. For example, reconstruction data 150-1 indicates how to convert the rendition of signal 115-0 into the rendition of signal 115-1; reconstruction data 150-2 indicates how to convert the rendition of signal 115-1 into the rendition of signal 115-2; reconstruction data 150-3 indicates how to convert the rendition of signal 115-2 into the rendition of signal 115-3; and so on.

Reconstruction data 150 can include any of multiple different types of data indicating how to reconstruct the signal 115 at higher levels of quality. For example, reconstruction data include any of one or more sets, planes, etc., of different types of reconstruction data such as parameters of upsampling operations, quantization threshold information, residual data, motion zones, motion vectors, spectral information on noise, meta-data, adjustments, class information, etc., to reconstruct signal 115 at different levels.

In an additional non-limiting example details of downsampling a respective signal and producing reconstruction data, the signal processor can be configured to test and create different sets of reconstruction data to convert a rendition of the signal from one level of quality to another.

As mentioned, reconstruction data 150 can include any suitable data for signal processing. For example, each set of reconstruction data 150 can include metadata, residual data, etc. Metadata can include data such as a set of one or more upsampling operations in which to convert the rendition of signal from one level of quality to the next; the residual data can indicate information such as adjustments to be made to signal elements at the different levels of quality, and so on. More specifically, in one embodiment, the reconstruction data 150 can specify multi-plane element setting information indicating parameters such as color or elements, intensity, upsample operations, parameters of upsampling operations, quantization thresholds, residual data within an image/frame, motion zones, motion vectors, residual data indicating adjustments to apply after motocompensation of elements coming from a previous image/frame, spectral information on noise, other meta-data, etc.

Note again that the sets of reconstruction data can include residual data indicating adjustments to be made during upsampling the rendition of signal at a first level of quality into the rendition of signal at a next higher level of quality.

Embodiments herein include utilizing inheritance to reduce an amount of bits, symbols, etc., that are needed to encode reconstruction data 150. For example, the elements in the renditions of the signal at the lower levels of quality are assigned certain setting information. In certain cases, the setting information assigned to a respective element at a lower level of quality can be reused for subdivisions of the respective element at higher levels of quality. In other words, a parent element at one level of quality can be divided into multiple sub-elements for the next level of quality. Each sub-element (and corresponding sub-elements into which the sub-element is divided at higher levels of quality) can inherit one or more of the attribute settings of the parent element.

In this instance, rather than encode reconstruction data at higher levels of quality to duplicate the settings of the parent for each sub-element, embodiments herein include using appropriate symbols to notify signal processor 100-2 (e.g., a decoder) of which sub-elements inherit attribute settings of the parent element.

In accordance with further embodiments, signal processor 100-2 receives reconstruction data 150 to reconstruct the signal 115 at the first level of quality in the hierarchy. The signal processor 100-2 can receive the reconstruction data 150 over a respective

communication link.

FIG. 2 is an example diagram illustrating dividing respective parent elements at a first level of quality into multiple sub-elements at a next higher level of quality according to embodiments herein.

In one embodiment, the signal 115 represents image information. Assume in this non-limiting example that the signal 115 and corresponding reconstruction data indicates how to convert or expand a lower resolution image into a higher resolution image, with a given scale factor (e.g., in this non-limiting example a scale factor of 2).

Further, assume that the sets of encoded reconstruction data 150, when decoded, indicate how to control settings of image elements at each level of quality. For example, image 210-1 at level of quality J includes a field of image elements W; image 210-2 at level of quality J+1 includes field of image elements X; image 210-3 includes field of image elements Y; etc.

The reconstruction data for level of quality J indicates how to control settings of image elements W in image 210-1 (e.g., rendition of signal 115-0); the reconstruction data for level of quality J+1 indicates how to convert and generate setting information for each image element W in image 210-1 that is split into four X elements in image 210-2; the reconstruction data for level of quality J+2 indicates how to convert and generate setting information for each image element X in image 210-2 that is split into four Y elements in image 210-3; and so on. Thus, reconstruction data at the higher levels of quality are dependent upon the reconstruction data at lower levels of quality.

FIG. 3 is an example diagram illustrating use of reconstruction data according to embodiments herein.

In one embodiment, signal processor 100-1 such as a decoder resource selectively retrieves reconstruction data 150 from repository 180. The repository 180 stores groupings of reconstruction data A1...A8, B1...B8, C1...C8, D1...D8, etc. Note that the number of different levels of quality is shown by way of non-limiting example only and that the reconstruction data can include any suitable number of tiers (e.g., levels of quality).

Reconstruction data A1 in grouping of reconstruction data A indicates how to reconstruct image/frame F1 of signal 115 at a lowest level of quality; reconstruction data A2 indicates

how to reconstruct image/frame F1 of signal 115 at level of quality #2 (e.g., one level of quality higher than level of quality #1) based on a rendition of the image/frame F1 generated for level of quality #1; reconstruction data A3 indicates how to reconstruct image/frame F1 of signal 115 at level of quality #3 (e.g., one level of quality higher than level of quality #2) based on a rendition of the image/frame F1 generated for level of quality #2; reconstruction data A4 indicates how to reconstruct image/frame F1 of signal 115 at level of quality #4 (e.g., one level of quality higher than level of quality #3) based on a rendition of the image/frame F3 generated for level of quality #3; reconstruction data A5 indicates how to reconstruct image/frame F1 of signal 115 at level of quality #5 (e.g., one level of quality higher than level of quality #4) based on a rendition of the image/frame F1 generated for level of quality #4; reconstruction data A6 indicates how to reconstruct image/frame F1 of signal 115 at level of quality #6 (e.g., one level of quality higher than level of quality #5) based on a rendition of the image/frame F1 generated for level of quality #5; reconstruction data A7 indicates how to reconstruct image/frame F1 of signal 115 at level of quality #7 (e.g., one level of quality higher than level of quality #6) based on a rendition of the image/frame F1 generated for level of quality #6; reconstruction data A8 indicates how to reconstruct image/frame F1 of signal 115 at level of quality #8 (e.g., one level of quality higher than level of quality #7) based on a rendition of the image/frame F1 generated for level of quality #7. Thus, creating the rendition of signal 115 at the higher levels of quality depends on proper decoding reconstruction data at the lower levels of quality.

Reconstruction data B1 in grouping of reconstruction data B indicates how to reconstruct image/frame F2 of signal 115 at a lowest level of quality; reconstruction data B2 indicates how to reconstruct image/frame F2 of signal 115 at level of quality #2 (e.g., one level of quality higher than level of quality #1) based on a rendition of the image/frame F2 generated for level of quality #1; reconstruction data B3 indicates how to reconstruct image/frame F2 of signal 115 at level of quality #3 (e.g., one level of quality higher than level of quality #2) based on a rendition of the image/frame F2 generated for level of quality #2; reconstruction data B4 indicates how to reconstruct image/frame F2 of signal 115 at level of quality #4 (e.g., one level of quality higher than level of quality #3) based on

a rendition of the image/frame F2 generated for level of quality #3; reconstruction data B5 indicates how to reconstruct image/frame F2 of signal 115 at level of quality #5 (e.g., one level of quality higher than level of quality #4) based on a rendition of the image/frame F2 generated for level of quality #4; reconstruction data B6 indicates how to reconstruct image/frame F2 of signal 115 at level of quality #6 (e.g., one level of quality higher than level of quality #5) based on a rendition of the image/frame F2 generated for level of quality #5; reconstruction data B7 indicates how to reconstruct image/frame F2 of signal 115 at level of quality #7 (e.g., one level of quality higher than level of quality #6) based on a rendition of the image/frame F2 generated for level of quality #6; reconstruction data B8 indicates how to reconstruct image/frame F2 of signal 115 at level of quality #8 (e.g., one level of quality higher than level of quality #7) based on a rendition of the image/frame F2 generated for level of quality #7.

In a similar manner, each of the different groupings of reconstruction data in repository 180 enables reconstruction of a respective image/frame of the signal 115.

Note that additional example details for creating tiered sets of reconstruction data can be found in the related applications incorporated herein by reference.

In one embodiment, the sequence of frames F1, F2, F3, F4, etc., in signal is a sequence of images that appears as a moving picture or video when played back by a media player 310.

As discussed herein, the signal processor 100-1 transmits all or selected portions of the reconstruction data in data stream 400 to signal processor 100-2 (e.g., a decoder resource). Signal processor 100-2 is configured to reconstruct renditions of the original signal 115 based on the received reconstruction data.

In one embodiment, during transmission of reconstruction data, the signal processor 100-1 varies a level of quality of the reconstruction data transmitted to the signal processor 100-2. The signal processor 100-2 decodes the received reconstruction data to play back the signal at different levels of quality on playback device 310.

FIG. 4 is an example diagram illustrating a data stream including different levels of quality of reconstruction data according to embodiments herein.

As mentioned above, in one embodiment, the signal processor 100-1 varies the level of quality of reconstruction data transmitted to the signal processor 100-2.

For example, the signal processor 100-1 transmits a first set of reconstruction data (e.g., reconstruction data A1, A2, A3, A4, A5, A6, A7, A8) to the decoder resource in signal processor 100-2 for play back of a first portion (e.g., a frame such as F1) of the signal 115.

The signal processor 100-1 transmits a second set of reconstruction data (e.g., B1, B2, B3, B4, B5) to the decoder resource for play back of a second portion (e.g., a frame such as frame F2) of the signal 115.

The first set of reconstruction data (e.g., grouping A reconstruction data including X=8 tiers of reconstruction data) in data stream 400 indicates how to reconstruct a rendition of the first portion of the signal (e.g., frame F1) up to level of quality #8 in the tiered hierarchy.

The second set of reconstruction data (e.g., grouping B reconstruction data including Y=5 tiers of reconstruction data) in data stream 400 indicates how to reconstruct a rendition of the second portion of the signal (e.g., frame F2) up to level of quality #5 in the tiered hierarchy.

The third set of reconstruction data (e.g., grouping C reconstruction data including 5 tiers of reconstruction data) in data stream 400 indicates how to reconstruct a rendition of a third portion of the signal (e.g., frame F3) up to level of quality #5 in the tiered hierarchy.

The fourth set of reconstruction data (e.g., grouping D reconstruction data including 8 tiers of reconstruction data) indicates how to reconstruct a rendition of a fourth portion of the signal (e.g., frame F4) up to level of quality #8 in the tiered hierarchy.

In this manner, the signal processor 100-1 selects and varies a level of quality of reconstruction data to signal processor 100-2 for playback of the signal 115 by media player 310.

FIG. 5 is another example diagram illustrating variations in the level of quality of reconstruction data transmitted to a decoder according to embodiments herein.

The tiers of reconstruction data to reconstruct rendition of signal 115 can be transmitted at different levels of quality for a number of different reasons.

For example, in one embodiment, the reconstruction data for grouping B, C, and D may be transmitted from the signal processor 100-1 to a decoder resource at selected lower levels of quality (e.g., levels of quality beneath the highest level of quality) instead of the highest level of quality in response to detecting an inability to transmit, due to network congestion

in a respective communication link, the reconstruction data according to the highest level of quality.

As shown in this example, the signal processor 100-1 transmits reconstruction data A1...A8 for reconstruction of image/frame F1; the signal processor 100-1 transmits reconstruction data B1...B4 for reconstruction of image/frame F2; the signal processor 100-1 transmits reconstruction data C1...C4 for reconstruction of image/frame F3; the signal processor 100-1 transmits reconstruction data D1...D5 for reconstruction of image/frame F4; the signal processor 100-1 transmits reconstruction data E1...E8 for reconstruction of image/frame F5; and so on.

Thus, in one embodiment, the signal processor varies a highest level of quality of reconstruction data transmitted to a decoder resource for each of multiple images/frames of the signal.

In accordance with further embodiments, the signal processor 100-1 varies the highest level of quality of reconstruction data transmitted to the decoder in order to transmit a substantially constant bit rate of tiered reconstruction data to the decoder resource for each of multiple successive images/frames of the signal. For example, the reconstruction data at higher levels of quality for a respective image/frame can include a considerable amount of data. Eliminating transmission of the reconstruction data at a higher level of quality ensures that at least the lower level of quality reconstruction data can be received and played back by a media player without delay. Thus, network congestion can cause playback of the signal at a lower level of quality.

In one embodiment, the signal processor 100-1 varies the level of quality of the reconstruction data transmitted to the decoder to facilitate playback of the signal in substantially real-time by the decoder resource. For example, rather than delay transmission of high resolution, "live" images to the decoder, the signal processor 100-1 may reduce the level of quality of reconstruction data transmitted to a decoder to ensure that the decoder can playback the signal without delay according to at least a low level of quality. Thus, embodiments herein support playback of "live" or substantially "live" video feeds on multiple decoding resources with different computing power (and/or display device resolutions), at the same time eliminating the need to transmit information that

certain decoders wouldn't be able to leverage.

Note also that the signal 115 and corresponding reconstruction data can be derived from an older recording. In case of network congestion, for example, reducing the level of quality of reconstruction data transmitted for one or more images/frames during congestion enables the decoder to play back the signal without delay.

FIG. 6 is an example diagram illustrating variations in the level of quality of reconstruction data forwarded to a decoder according to embodiments herein.

As shown, the signal processor 100-1 initially transmits the reconstruction data A, B, and C, up to a first level of quality (e.g., level of quality #4) for images/frames F1, F2, and F3. Level of quality #4 may be a default level of quality in which to transmit the reconstruction data.

The signal processor 100-1 can be configured to transmit the reconstruction data following time T1 at a second level of quality (e.g., level of quality #8) in response to receiving a request from a source such as a user to transmit the reconstruction data at a different level of quality. For example, a source such as the decoder resource, user, etc., can request transmission of the signal in accordance with a higher or lower quality than a previously transmitted image/frame. In response to the request to transmit the reconstruction data at a different level of quality, the signal processor 100-1 transmits the reconstruction data at the newly requested level of quality. In this example, the signal processor 100-1 transmits images/frames F4, F5, and subsequent images/frames of reconstruction data, at the higher of quality in response to a user requesting to view the signal 115 at a higher level of quality. The decoder resource receives the reconstruction data for the images/frames as transmitted by the signal processor 100-1 and plays back the signal 115 in accordance with the different levels of quality. For example, the signal processor 100-2 decodes the received reconstruction data and plays back images/frames of signal 115 up to image/frame F3 at the first level of quality; the signal processor 100-2 decodes the reconstruction data and plays back subsequent images/frames (e.g., images/frames after F4) of signal 115 at the second level of quality.

FIG. 7 is an example diagram illustrating transmission of a group of lower level of quality reconstruction data followed by transmission of higher level of quality reconstruction data

according to embodiments herein.

In accordance with further embodiments, the signal processor 100-1 can be configured to transmit the lower levels of quality of reconstruction data for each of multiple portions such as images/frames of the signal 115 followed by transmission of higher levels of quality of reconstruction data.

For example, as shown, the signal processor 100-1 produces a first set of reconstruction data to include reconstruction data A1, ...A4, B1, ...B4, C1, ...C4, etc. and transmits this group of reconstruction data in data stream 800 to a decoder. Based on this initial set of reconstruction data, the decoder is able to play back the signal at a respective lower level of quality.

In one embodiment, the signal processor transmits the first set of reconstruction data 810-1 to the decoder resource to enable navigation amongst the signal 115 in accordance with a first level of quality (e.g., by way of non-limiting example, level of quality #4). Transmission of the first set of reconstruction data in data stream 800 can be achieved in relatively little time because the first set of reconstruction data 810-1 is relatively compact as it enables reconstruction according to a low level of quality.

Based on input from a user, the decoder resource initiates playback of the first set of reconstruction data 810-1 enabling a respective user to quickly navigate (e.g., via commands such as fast forward, reverse, etc.) amongst playback of a low-resolution (e.g., lower level of quality) version of the signal. Based on viewing the low-resolution signal generated via reconstruction data 810-1, the user can select and generate a pointer value indicating a location in the signal for playback at a higher level of quality.

In response to the selection of the location in the low-resolution signal, the signal processor 100-1 produces a second set of reconstruction data including the reconstruction data for all images/frames of the signal at the higher levels of quality (e.g., reconstruction data at higher levels of quality not yet sent to the decoder) or a set of reconstruction data starting at the higher levels of quality (that has not yet been sent) starting at the requested location as by the pointer value. The signal processor 100-1 transmits the second set of reconstruction data 810-2 to the decoder resource for play back of the signal in accordance with the higher level of quality.

Thus, the first set of reconstruction data 810-1 enables playback of the signal according to the first level of quality (e.g., level of quality #4). A combination of the first set of reconstruction data 810-1 and second set of reconstruction data 810-2 enables playback of the signal in accordance with a higher level of quality (e.g., level of quality #8).

As discussed herein, the second set of reconstruction data 810-2 (e.g., including reconstruction data to reconstruct the signal at the higher level of quality) can be supplemental reconstruction data with respect to the first set of reconstruction data. That is, the reconstruction data A5...A8 indicates how to modify upper levels of quality of a rendition of the signal produced by reconstruction data A1...A4; the reconstruction data B5...B8 indicates how to modify a rendition of the signal produced by reconstruction data B1...B4; and so on.

In this example, assume that a user receives the first set of reconstruction data 810-1 to scan corresponding content for areas of interest at a lower level of quality. Assume the user views the content at the lower level of quality #4 and generates a request to view a portion of the signal following grouping D at a higher resolution. In one embodiment, in response to receiving the request, the signal processor 100-1 immediately streams the reconstruction data D5...D8, E5...E8, etc., to the user for playback of the signal starting at the selected location. In such an instance, there is no need for the signal processor 100-1 to transmit reconstruction data A5...A8, B5...B8, C5...C8, because the user (in this example) is not interested in viewing this data in higher resolution. Accordingly, a user can view content (e.g., signal 115) at a lower level of quality and decide which portions, if any, to view in a higher resolution.

FIG. 8 is an example diagram illustrating a fee structure for distribution of reconstruction data to playback a rendition of a signal according to embodiments herein.

For example, in accordance with one embodiment, different levels of quality of the reconstruction data can be distributed based on a fee schedule. A user operates the decoder resource and initiates playback of signal 115 based on retrieval of the reconstruction data. The user is charged a different fee (e.g., amount of money) depending on a level of quality of the reconstruction data transmitted to the decoder resource and played back by the user.

In this example, the user is charged fee 700-1 based on transmission and receipt of sets of

the reconstruction data up to level of quality #5; the user is charged fee 700-2 based on transmission and receipt of the reconstruction data up to level of quality #7; the user is charged fee 700-3 based on transmission and receipt of the reconstruction data up to level of quality #9, and so on.

Note that, as indicated in the above example, the user operating signal processor 100-2 (e.g., a decoder) can initially receive reconstruction data according to a first level of quality (e.g., level of quality #5) for playback and viewing of signal 115. Transmission of the lower level of quality reconstruction data may be free to the user, or characterized by a different fee. Based on a request from the user to view the signal at a higher level of quality, the signal processor 100-1 retrieves and transmits the reconstruction data up to a second, higher level of quality (e.g., level of quality #7, level of quality #9, etc.) to satisfy the user's request. The user may be charged a respective fee as discussed above for receipt of the reconstruction data at the higher level of quality.

In another embodiment, regardless of the fee charged to the user operating signal processor 100-2 (e.g., a decoder), a different royalty fee structure may be applied to the operator of the signal processor 100-1 based on the levels of quality transmitted to signal processor 100-2.

FIG. 9 is an example diagram illustrating use of digital rights management algorithms at one or more levels of quality according to embodiments herein.

For example, as mentioned, each portion (e.g., image, frame, etc.) of signal 115 can be defined by a respective tiered set of reconstruction data to reconstruct that portion of the signal. Embodiments herein include implementing digital rights management 910 with respect to selected lower tiers of the sets of reconstruction data (e.g., by way of non-limiting example, the level of quality #1).

In one embodiment, use of digital rights management 901 prevents unauthorized decoding of the reconstruction data at the lower level of quality. For example, the signal processor 100-2 executes a respective application enabling decoding of the lowest level of quality #1. Higher tiers of the reconstruction data are accessible and may not be protected by digital rights management. The signal processor 100-2 decodes the lower level of quality #1 of reconstruction data (e.g., reconstruction data A1, B1, C1, D1, E1, etc.) using a respective

digital rights management application. The additional reconstruction data (e.g., reconstruction data at level of quality #2, level of quality #3, level of quality #4, etc.) at higher levels of quality can be decoded without the digital rights management application.

In one embodiment, the reconstruction data at level of quality #1 (e.g., reconstruction data A1, B1, C1, D1, E1, ...) is encrypted in accordance with an appropriate protocol. The signal processor 100-2 receives a respective decryption key to decrypt the received reconstruction data at level of quality #1. As mentioned, there is no need to encrypt the higher level of quality reconstruction data because use of the reconstruction data at level of quality #2, #3, etc., depends on proper decoding of reconstruction data at level of quality #1. Without the ability to decode the lower level of quality reconstruction data at level of quality #1, a decoder resource that does not have a respective decryption key is unable to use the higher level of quality reconstruction data to produce a meaningful rendition of the signal. In other words, use of the higher level of quality reconstruction data is dependent on successful decoding of corresponding lower level of quality reconstruction data.

FIG. 10 is an example diagram illustrating redundancy of reconstruction data at one or more lower levels of quality according to embodiments herein.

In accordance with such an embodiment, the signal processor generates the sets of reconstruction data to include redundant encoding at the lower level of quality to enable playback of the lower level of quality reconstruction data in the event of an error. The signal processor generates higher level of quality reconstruction data to include non-redundant encoding. Accordingly, a user receiving the reconstruction data more likely will be able to playback the signal with graceful degradation in the event of an error, as the higher level of quality reconstruction data may be corrupt, but the "coarse information" contained in the lower level of quality of the signal will be intact.

As an example, the redundancy information RA can be based on reconstruction data A1, A2, A3, A4, and A5; the redundancy information RB can be based on reconstruction data B1, B2, B3, B4, and B5; the redundancy information RC can be based on reconstruction data C1, C2, C3, C4, and C5; etc.

FIG. 11A is an example diagram illustrating reconstruction data parsed based on tiles according to embodiments herein.

In one embodiment, the reconstruction data is parsed into groupings (e.g., A, B, C, D, etc.); each of the groupings of reconstruction data includes information to reconstruct a time-based portion (e.g., image/frame) of the signal. For example, as mentioned, reconstruction data A includes information indicating how to reconstruct image/frame F1; reconstruction data B includes information indicating how to reconstruct image/frame F2; reconstruction data C includes information indicating how to reconstruct image/frame F3; etc.

Each of the groupings of reconstruction data can include multiple sequences of hierarchically tiered reconstruction data from a lowest level of quality to a higher level of quality in the hierarchy. For example, the reconstruction data for reconstructing a portion (e.g., image/frame F1) of the signal at tile T1 in grid 1110 includes sequence of reconstruction data A1-T1, A2-T1, A3-T1, A4-T1, A5-T1, A6-T1, A7-T1, and A8-T1; the reconstruction data for reconstructing a portion (e.g., image/frame F1) of the signal at tile T2 includes a sequence of reconstruction data A1-T2, A2-T2, A3-T2, A4-T2, A5-T2, A6-T2, A7-T2, and A8-T2; the reconstruction data for reconstructing a portion (e.g., image/frame F1) of the signal at tile T3 includes sequence of reconstruction data A1-T3, A2-T3, A3-T3, A4-T3, A5-T3, A6-T3, A7-T3, and A8-T3; and so on.

The reconstruction data for reconstructing a portion (e.g., image/frame F2) of the signal at tile T1 includes sequence of reconstruction data B1-T1, B2-T1, B3-T1, B4-T1, B5-T1, B6-T1, B7-T1, and B8-T1; the reconstruction data for reconstructing a portion (e.g., image/frame F1) of the signal at tile T2 includes a sequence of reconstruction data B1-T2, B2-T2, B3-T2, B4-T2, B5-T2, B6-T2, B7-T2, and B8-T2; the reconstruction data for reconstructing a portion (e.g., image/frame F1) of the signal at tile T3 includes sequence of reconstruction data B1-T3, B2-T3, B3-T1, B4-T1, B5-T1, B6-T1, B7-T1, B8-T1; and so on.

Thus, each of the multiple sequences of tiered reconstruction data from a lowest level of quality to the higher level of quality indicates settings of a respective tile of contiguous elements associated with the signal.

As mentioned, grid 1110 illustrates the tiles in the rendition of signal 115 produced by the decoder using the reconstruction data split up according to tiles. Each tile at the lowest

level of quality in the hierarchy can include one or more elements. As discussed herein, each element in the tile at a respective level of quality in the hierarchy is divided into multiple sub-elements at a next higher level of quality; the reconstruction data for the tile at each respective level of quality indicates the settings of the elements. Accordingly, each element in the tile at the lowest level of quality is subdivided at each level into sub-elements up to the highest level of quality for the respective tile.

In one embodiment, the signal processor 100-2 includes multiple processors. Each processor can be assigned to produce a respective rendition of the signal for a given tile (e.g., the tile can include a grouping of elements) based on respective reconstruction data at the multiple levels of quality for the tile. The tiles of elements are then combined to produce an overall rendition of the signal 115 for playback. Processing the tiles in parallel using one or more processors enables a quicker reconstruction of the signal for playback on a playback device. For example, each processor can be configured to reconstruct the tile of the signal 115 for each different image/frame.

FIG. 11B is another example diagram illustrating reconstruction data parsed based on tiles according to embodiments herein.

In one embodiment, the reconstruction data is parsed into groupings (e.g., A, B, C, D, etc.); each of the groupings of reconstruction data includes entropy encoded data. The size of each tile of entropy encoded data at each different level of quality can vary as shown. For example, tile A1-T1 includes entropy encoded data for more elements at the level of quality #1 than does tile A1-T2; tile A1-T2 includes entropy encoded data for more elements at the level of quality #1 than does tile A1-T3. Thus, the size and specific region of coverage of tiles of entropy encoded reconstruction data at a given level of quality can vary.

Additionally, the number of tiles and respective coverage for each tile of entropy encoded reconstruction data can vary for different levels of quality. For example, level of quality #1 includes three tiles of entropy encoded reconstruction data; level of quality #2 includes five tiles of entropy encoded reconstruction data; level of quality #3 includes fifteen tiles of entropy encoded reconstruction data; etc.

Thus, each of the multiple sequences of tiered reconstruction data from a lowest level of

quality to the higher level of quality indicates settings of a respective tile of contiguous elements associated with the signal.

FIG. 12 is an example diagram illustrating different ways of reconstruction data for each of multiple tiles according to embodiments herein.

As shown in data stream 1210-1, transmission of the reconstruction data from the signal processor 100-1 to the decoder resource (i.e., signal processor 100-2) can include serially transmitting each of the multiple sequences (e.g., sequence A1-T1 A2-T1, A3-T1, A4-T1, A5-T1, A6-T1, A7-T1, and A8-T1; sequence A1-T2, A2-T2, A3-T2, A4-T2, A5-T2, A6-T2, A7-T2, and A8-T2; sequence A1-T3, A2-T3, A3-T3, A4-T3, A5-T3, A6-T3, A7-T3, and A8-T3; and so on) in sequential order, one after another, in a bit stream (i.e., data stream 1210-1) to the decoder.

The signal processor 100-2 can be configured to provide marker information in the data stream 1210-1 to indicate a respective beginning and end of each sequence of tiered reconstruction data for each tile. For example, the signal processor 100-1 can insert a marker (e.g., symbol, demarcation, etc.) between reconstruction data A8-T1 and A1-T2, between reconstruction data A8-T2 and A1-T3, and so on.

In accordance with another embodiment, transmission of the reconstruction data for a respective portion of the signal from the signal processor 100-1 to a respective decoder can include transmitting, for a given image/frame of reconstruction data, the tiered reconstruction data in data stream 1210-2 starting from reconstruction data at the lower levels of quality to reconstruction data for the higher level of quality for the multiple sequences associated with a portion of the signal.

For example, in accordance with such an embodiment, the signal processor 100-1 transmits the lower level of quality entropy encoded reconstruction data including A1-T1, A1-T2, A1-T3, A1-T4, A1-T5, A1-T6, etc., followed by the sequence A2-T1, A2-T2, A2-T3, A2-T4, A2-T5, A2-T6, etc., followed by A3-T1 A3-T2, A3-T3, A3-T4, A3-T5, A5-T6, etc., and so on, as shown in data stream 1210-2. In accordance with such an embodiment, the signal processor 100-1 can provide marker information (e.g., unique symbols) in the data stream 1210-2 to indicate a respective beginning and end of tiered reconstruction data for each level of quality. For example, the signal processor 100-1 can provide a marker

between A1-T*v* and A2-T1 (where *v* is the highest number of tile); the signal processor 100-1 can provide a marker between A2-T*v* and A3-T1 (where *v* is the highest number of tile); and so on.

As mentioned, the decoder resource can include multiple processors, each of which is configured to decode entropy encoded data for a respective tile to produce a tile of the reconstruction data. A combination of entropy decoding tiles at a given level of quality produces the reconstruction data for the while level of quality. For example, each of multiple processors can entropy decode entropy encoded data for a respective tile at a given level of quality. Based on entropy decoding of all tiles of entropy encoded data, each respective processor produces reconstruction data to reconstruct the tile of elements at the corresponding level of quality. Using global upsample operations applied to the frame as a whole for the given level of quality, the respective reconstruction data for the level of quality is then used to upsample a rendition of the signal to a next higher level of quality. This process of entropy decoding different sized and/or different numbers of tiles at the different levels of quality can be repeated at each level until reproducing the signal at the highest level of quality.

FIG. 13 is an example diagram illustrating buffering of reconstruction data according to embodiments herein.

As shown in FIG. 13, the signal processor 100-1 can be configured to transmit the reconstruction data for a given portion (such as a respective image/frame) of the signal over multiple segments (e.g., two or more segments) of a data stream 1310.

More specifically, in one embodiment, the signal processor 100-1 partitions the data stream 1310 into segments 1320 (e.g., segment 1320-1, segment 1320-2, segment 1320-3, etc.) for sending the reconstruction data to remote resource such as a decoder. In one embodiment, each segment 1320 of the data stream 1310 supports transmission of a substantially equal number of data bits. In general, each segment can include reconstruction data to reconstruct a portion of the signal 115 such as a respective image/frame.

As shown, the signal processor 100-1 generates segment 1320-1 of the data stream 1310 to include reconstruction data A1, A2, A3 ...A8 to play back a first image/frame of the signal; the signal processor 100-1 generates the segment 1320-2 of the data stream 1310 to include

reconstruction data B1, B2, B3, .. B8 to play back a second image/frame of the signal; the signal processor 100-1 generates the segment 1320-3 of the data stream 1310 to include reconstruction data C1, C2, C3, ..., C8 to play back a third image/frame of the signal.

In one embodiment, the signal processor 100-1 populates the first segment 1320-1 of the data stream 1310 to include multiple levels of quality of reconstruction data to reconstruct the first image/frame of the signal. The signal processor 100-1 populates the second segment 1320-2 of the data stream 1310 to include multiple levels of quality of reconstruction data to reconstruct the second image/frame of the signal. The signal processor 100-1 populates the second segment 1320-2 of the data stream 1310 to include: i) multiple levels of quality of reconstruction data to reconstruct the second image/frame of the signal, and ii) at least one level of quality of reconstruction data to reconstruct a third image/frame of the signal. The third segment 1320-3 includes additional reconstruction data to reconstruct the third image/frame. Thus, instead of transmitting reconstruction data in a corresponding segment of the data stream, the reconstruction data for a portion of the signal can be spread out over multiple segments.

In one embodiment, the decoder resource is configured to buffer the data stream 1310 transmitted by the signal processor 100-1. For example, when the point of received data is past reconstruction data D4, the signal processor 100-2 reconstructs the image/frame associated with segment 1320-3 based on the multiple levels of quality of reconstruction data C1...C6 in segment 1320-3 of the data stream 1310 as well as based on reconstruction data C7 and C8 in segment 1320-2 of the data stream 1310. In this manner, the higher level of quality reconstruction data can be spread out in different segments of data stream 1310. Buffering reconstruction data and delaying playback enables the decoder to receive the appropriate reconstruction data to decode the signal and playback the signal in accordance with level of quality #8.

FIG. 14 is an example block diagram of a computer system 800 providing signal processing according to embodiments herein.

Computer system 800 can be or include a computerized device such as a personal computer, processing circuitry, television, playback device, encoding device, workstation, portable computing device, console, network terminal, processing device, network device,

operating as a switch, router, server, client, etc.

Note that the following discussion provides a basic embodiment indicating how to carry out functionality associated with any of the resources as discussed herein such as signal processor 100-1, signal processor 100-2, media player, etc. However, it should be noted that the actual configuration of computer system 800 for carrying out the operations can vary depending on a respective application.

As shown, computer system 800 of the present example includes an interconnect 811 that couples computer readable storage media 812 such as a non-transitory type of media, computer readable, hardware storage medium, etc., in which digital information can be stored and retrieved. Computer system 800 can further include a processor 813, I/O interface 814, and a communications interface 817.

I/O interface 814 provides connectivity to repository 180, and if present, display screen, peripheral devices 816 such as a keyboard, a computer mouse, etc.

Computer readable storage medium 812 (e.g., a hardware storage media) can be any suitable device and/or hardware such as memory, optical storage, hard drive, floppy disk, etc. The computer readable storage medium can be a non-transitory storage media to store instructions associated with signal processor 840. The instructions are executed by a respective resource such as signal processor 840 to perform any of the operations as discussed herein.

Communications interface 817 enables computer system 800 to communicate over network 190 to retrieve information from remote sources and communicate with other computers, switches, clients, servers, etc. I/O interface 814 also enables processor 813 to retrieve or attempt retrieval of stored information from repository 180.

As shown, computer readable storage media 812 can be encoded with signal processor application 840-1 executed by processor 813 as signal processor process 840-2.

Note that the computer system 800 also can be embodied to include a computer readable storage medium 812 (e.g., a hardware storage media, non-transitory storage media, etc.) for storing data and/or logic instructions.

Computer system 800 can include a processor 813 to execute such instructions and carry out operations as discussed herein. Accordingly, when executed, the code associated with

signal processor application 840-1 can support processing functionality as discussed herein. As mentioned, the signal processors as discussed herein can be configured to support encoding and/or decoding.

During operation of one embodiment, processor 813 accesses computer readable storage media 812 via the use of interconnect 811 in order to launch, run, execute, interpret or otherwise perform the instructions of signal processor application 840-1 stored in computer readable storage medium 812. Execution of the signal processor application 840-1 produces processing functionality in processor 813. In other words, the signal processor process 840-2 associated with processor 813 represents one or more aspects of executing signal processor application 840-1 within or upon the processor 813 in the computer system 800.

Those skilled in the art will understand that the computer system 800 can include other processes and/or software and hardware components, such as an operating system that controls allocation and use of hardware processing resources to execute signal processor application 840-1 (e.g., encoder, decoder, etc.).

In accordance with different embodiments, note that computer system may be any of various types of devices, including, but not limited to, a personal computer system, desktop computer, laptop, notebook, netbook computer, mainframe computer system, handheld computer, workstation, network computer, application server, storage device, a consumer electronics device such as a camera, camcorder, set top box, mobile device, video game console, handheld video game device, a peripheral device such as a switch, modem, router, or, in general, any type of computing or electronic device.

FIG. 15 is an example flowchart 1500 illustrating a method of using reconstruction data according to embodiments herein.

In step 1510, the signal processor 100-1 retrieves reconstruction data from a repository 180. The retrieved reconstruction data is encoded in accordance with a tiered hierarchy including multiple levels of quality.

In step 1520, the signal processor 100-1 transmits the retrieved reconstruction data to a remote source such as a decoder. The decoder can be configured to reconstruct renditions of the signal based on the transmitted reconstruction data.

In step 1530, during the transmitting, the signal processor 100-1 varies a level of quality of the reconstruction data retrieved from the repository and transmitted to the decoder.

Note again that techniques herein are well suited for use in processing and reconstructing signals. However, it should be noted that embodiments herein are not limited to use in such applications and that the techniques discussed herein are well suited for other applications as well.

Based on the description set forth herein, numerous specific details have been set forth to provide a thorough understanding of claimed subject matter. However, it will be understood by those skilled in the art that claimed subject matter may be practiced without these specific details. In other instances, methods, apparatuses, systems, etc., that would be known by one of ordinary skill have not been described in detail so as not to obscure claimed subject matter. Some portions of the detailed description have been presented in terms of algorithms or symbolic representations of operations on data bits or binary digital signals stored within a computing system memory, such as a computer memory. These algorithmic descriptions or representations are examples of techniques used by those of ordinary skill in the data processing arts to convey the substance of their work to others skilled in the art. An algorithm as described herein, and generally, is considered to be a self-consistent sequence of operations or similar processing leading to a desired result. In this context, operations or processing involve physical manipulation of physical quantities. Typically, although not necessarily, such quantities may take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared or otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to such signals as bits, data, values, elements, symbols, characters, terms, numbers, numerals or the like. It should be understood, however, that all of these and similar terms are to be associated with appropriate physical quantities and are merely convenient labels. Unless specifically stated otherwise, as apparent from the following discussion, it is appreciated that throughout this specification discussions utilizing terms such as "processing," "computing," "calculating," "determining" or the like refer to actions or processes of a computing platform, such as a computer or a similar electronic computing device, that manipulates or transforms data represented as physical electronic or magnetic

quantities within memories, registers, or other information storage devices, transmission devices, or display devices of the computing platform.

While this invention has been particularly shown and described with references to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the present application as defined by the appended claims. Such variations are intended to be covered by the scope of this present application. As such, the foregoing description of embodiments of the present application is not intended to be limiting. Rather, any limitations to the invention are presented in the following claims.

We claim:

1. A method comprising:

retrieving reconstruction data and metadata, the retrieved reconstruction data and metadata being a subset of available data selected from a repository for distribution to a decoder, the retrieved reconstruction data encoded in accordance with a tiered hierarchy including multiple available levels of quality in which portions of a signal are encoded;

transmitting the retrieved reconstruction data to a decoder, the decoder configured to reconstruct renditions of the signal based on the transmitted reconstruction data; and

during the transmission, varying a level of quality of the reconstruction data retrieved and transmitted to the decoder.

2. The method as in claim 1, wherein varying the level of quality includes:

transmitting a first set of reconstruction data to the decoder for playback of a first portion of the signal, the first set of reconstruction data indicating how to reconstruct a rendition of the first portion of the signal up to a first level of quality in the tiered hierarchy; and

transmitting a second set of reconstruction data to the decoder for playback of a second portion of the signal, the second set of reconstruction data indicating how to reconstruct a rendition of the second portion of the signal up to a second level of quality in the tiered hierarchy, the second level of quality being of different resolution quality than the first level of quality.

3. The method as in claim 2, wherein the second set of reconstruction data is transmitted at the second level of quality instead of the first level of quality in response to detecting the bandwidth currently available in a transmission channel.

4. The method as in claim 2, wherein the second set of reconstruction data is transmitted at the second level of quality in response to receiving a request to transmit the second set of reconstruction data at the second level of quality instead of the first level of quality.

5. The method as in claim 2, wherein the second set of reconstruction data is transmitted at the second level of quality in response to detecting a characteristic of the decoding resource.

6. The method as in claim 1, wherein each of multiple levels of quality of the reconstruction data for a image/frame of the signal indicates how to reconstruct a rendition of the signal in accordance with

a different level of quality.

7. The method as in claim 1, wherein varying the level of quality includes:

for a first portion of the signal, producing a first set of reconstruction data to include a sequence of reconstruction data from a lowest level of quality in the hierarchy to the first level of quality;

transmitting the first set of reconstruction data to the decoder for playback of the first portion of the signal in accordance with the first level of quality;

for a second portion of the signal, producing a second set of reconstruction data to include a sequence of reconstruction data from the lowest level of quality in the hierarchy to the second level of quality, the second level of quality being different from the first level of quality; and

transmitting the second set of reconstruction data to the decoder for playback of the second portion of the signal in accordance with the second level of quality.

8. The method as in claim 1, wherein varying the level of quality of the reconstruction data transmitted to the decoder includes:

producing a first set of reconstruction data to include reconstruction data to reconstruct portions of the signal in accordance with a first level of quality in the hierarchy;
transmitting the first set of reconstruction data to the decoder to enable playback and navigation amongst the signal in accordance with the first level of quality;

producing a second set of reconstruction data to include reconstruction data to reconstruct the signal in accordance with a second level of quality in the hierarchy; and

subsequent to transmitting the first set of reconstruction data, transmitting the second set of reconstruction data to the decoder for playback of the signal in accordance with the second level of quality.

9. The method as in claim 8, wherein the second set of reconstruction data is supplemental reconstruction data with respect to the first set of reconstruction data, the second set of reconstruction data indicating how to modify a rendition of the signal generated based on the first set of reconstruction data to reconstruct the signal according to the second level of quality.

10. The method as in claim 1, wherein varying the level of quality of the reconstruction data transmitted to the decoder includes:

producing a first set of reconstruction data to reconstruct the signal in accordance with a first level of quality in the hierarchy;

transmitting the first set of reconstruction data to the decoder to enable navigation amongst the signal played back at the first level of quality;

receiving a pointer value indicating a location in the signal, the pointer value generated by a user viewing a playback of the signal at the first level of quality as generated based on the first set of reconstruction data;

producing a second set of reconstruction data to include reconstruction data to reconstruct the signal starting at the location as specified by the pointer value, the second set of reconstruction data encoded in accordance with a second level of quality in the hierarchy; and

transmitting the second set of reconstruction data to the decoder to enable playback, at the second level of quality, of portions of the signal following the location as specified by the pointer value.

11. The method as in claim 9, wherein the second set of reconstruction data is supplemental reconstruction data with respect to the first set of reconstruction data, the second set of reconstruction data indicating how to modify a rendition of the signal generated based on the first set of reconstruction data to reconstruct the signal starting at the location as specified by the pointer value according to the second level of quality.

12. The method as in claim 1 further comprising:

varying the level of quality of the reconstruction data to facilitate playback of the signal in substantially real-time by the decoder.

13. The method as in claim 1 further comprising:

implementing a fee schedule or a royalty schedule in which users are charged different fees/royalties depending on a level of quality of the reconstruction data transmitted to the decoders.

14. The method as in claim 1 further comprising:

encoding the reconstruction data to include a first set of reconstruction data and a second set of reconstruction data, the first set of reconstruction data configured to enable reconstruction of the signal up to a first level of quality in the hierarchy, the second set of reconstruction data

configured to enable reconstruction of the signal up to a second level of quality in the hierarchy, the second level of quality being higher than the first level of quality;

wherein the second set of reconstruction data is supplemental reconstruction data indicating adjustments to make to the signal at the first level of quality as generated based on the first set of reconstruction data in order to reconstruct the signal according to the second level of quality; and

implementing digital rights management with respect to only the first set of reconstruction data to prevent unauthorized decoding of the first set of reconstruction data.

15. The method as in claim 1 further comprising:

encoding the reconstruction data to include a first set of reconstruction data and a second set of reconstruction data, the first set of reconstruction data configured to enable reconstruction of the signal according to a first level of quality in the hierarchy, the second set of reconstruction data configured to enable reconstruction of the signal according to a second level of quality in the hierarchy, the second level of quality being higher than the first level of quality;

wherein the second set of reconstruction data is supplemental reconstruction data indicating adjustments to make to the signal at the first level of quality as generated based on the first set of reconstruction data in order to reconstruct the signal according to the second level of quality;

generating the first set of reconstruction data to include redundant encoding to enable playback of the first set of reconstruction data in the event of errors with respect to the first set of reconstruction data; and

generating the second set of reconstruction data to only include non-redundant encoding.

16. The method as in claim 1, wherein the reconstruction data is organized into groupings of reconstruction data, each of the groupings of reconstruction data representing a time-based portion of the signal, each of the groupings of reconstruction data including space-based portions segments of tiered reconstruction data; and

wherein each of the segments of tiered reconstruction data indicates reconstruction data at a given level of quality for a respective tile of contiguous elements associated with the signal.

17. The method as in claim 16, wherein transmitting the retrieved reconstruction data to the decoder includes:

transmitting each of the multiple space-based segments in sequential order, one complete segment after another, in a bitstream to the decoder; and

providing marker and/or index information in the bitstream to indicate a respective beginning and end of each complete space-based segment.

18. The method as in claim 16, wherein transmitting the retrieved reconstruction data to the decoder includes:

transmitting the space-based segments of tiered reconstruction data in a bitstream starting from reconstruction data for the multiple segments for the lower levels of quality to reconstruction data for the multiple segments for the higher level of quality;

providing information in the bitstream to indicate a respective beginning and end of tiered reconstruction data for each level of quality and for each segment.

19. The method as in claim 1, wherein transmitting the retrieved reconstruction data to a decoder further comprises:

varying a highest level of quality of reconstruction data transmitted to the decoder for each portion of the signal in order to transmit a substantially constant bit rate of tiered reconstruction data to the decoder for each portion of multiple successive portions of the signal.

20. The method as in claim 1 further comprising:

partitioning a data stream into multiple segments including at least a first segment and a second segment, the first segment including reconstruction data to play back a first portion of the signal, wherein the first portion of the signal is an image/frame, the second segment including reconstruction data to play back a second portion of the signal, wherein the second portion of the signal includes a set of at least one subsequent images/frames;

populating the first segment of the data stream to include multiple levels of quality of reconstruction data to reconstruct the first portion of the signal; and

populating the second segment of the data stream to include: i) multiple levels of quality of reconstruction data to reconstruct the second portion of the signal, and ii) at least one level of quality of additional reconstruction data to reconstruct the first portion of the signal.

21. The method as in claim 20, wherein the decoder is configured to buffer the data stream and reconstruct the first portion of the signal based on the multiple levels of quality of reconstruction data in the first segment and the at least one level of quality of additional reconstruction data in the

second segment.

22. The method as in claim 20, wherein the first portion of the signal is an I-frame (Intra frame) and the second portion includes one or more P-frames (Predicted frames).

23. The method as in claim 22, wherein the decoder reconstructs the rendition of the second portion of the signal and of the subsequent portions of the signal also based on the additional reconstruction data pertaining to the first portion of the signal contained in the second segment.

24. The method as in claim 7, further comprising:

producing the first set of reconstructions data to specify a manner in which to upsample a rendition of the first portion of the signal at the lowest level of quality to a rendition of the first portion of the signal at the first level of quality; and

producing the second set of reconstructions data to specify a manner in which to upsample a rendition of the second portion of the signal at the lowest level of quality to a rendition of the second portion of the signal at the second level of quality.

25. The method as in claim 24, wherein producing the first set of reconstruction data and the second set of reconstruction data includes:

iteratively downsampling a rendition of the first portion of the signal from a highest level of quality to produce the first set of reconstruction data; and

iteratively downsampling a rendition of the second portion of the signal from the highest level of quality to produce the second set of reconstruction data.

26. The method as in claim 1, wherein varying the level of quality includes:

for a first portion of the signal, producing a first set of reconstruction data to include a first sequence of reconstruction data specifying how to upsample a lowest resolution of the first portion of the signal to a first resolution in the tiered hierarchy;

transmitting the first set of reconstruction data to the decoder for playback of the first portion of the signal in accordance with the first resolution;

for a second portion of the signal, producing a second set of reconstruction data to include a second sequence of reconstruction data specifying how to upsample a lowest resolution of the second portion of the signal to a second resolution in the tiered hierarchy; and

transmitting the second set of reconstruction data to the decoder for playback of the second portion of the signal in accordance with the second resolution.

27. The method as in claim 1, further comprising:

iteratively downsampling a rendition of a first portion of the signal at a highest resolution in the tiered hierarchy to successively lower resolutions in the tiered hierarchy to produce a first sequence of reconstruction data, the first sequence of reconstruction data encoded to specify how to upsample a rendition of the first portion of the signal from a lowest resolution in the tiered hierarchy; and

iteratively downsampling a rendition of a second portion of the signal at the highest resolution in the tiered hierarchy to successively lower resolutions in the tiered hierarchy to produce a second sequence of reconstruction data, the second sequence of reconstruction data encoded to specify how to upsample a rendition of the second portion of the signal from the lowest resolution in the tiered hierarchy.

28. The method as in claim 27, wherein the tiered hierarchy includes a first resolution level and a second resolution level that reside between the lowest resolution and the highest resolution in the tiered hierarchy; and

wherein varying the level of quality of the reconstruction data transmitted to the decoder includes: i) transmitting fewer-than-all portions of the first sequence of reconstruction data to the decoder to upsample a rendition of the first portion of the signal up to the first resolution level; and ii) transmitting fewer-than-all portions of the second sequence of reconstruction data to the decoder to upsample a rendition of the second portion of the signal up to the second resolution level.

29. The method as in claim 1, wherein varying the level of quality includes:

transmitting a first set of reconstruction data to the decoder for reproducing a first image frame of the signal, the first set of reconstruction data specifying upsample operations indicating how to upsample and reconstruct a rendition of the first image frame of the signal up to a first level of quality in the tiered hierarchy; and

transmitting a second set of reconstruction data to the decoder for reproducing a second image frame of the signal, the second set of reconstruction data specifying upsample operations indicating how to upsample and reconstruct a rendition of the second image frame of the signal up to a second level of quality in the tiered hierarchy, the second level of quality being of different

resolution quality than the first level of quality.

30. Computer-readable storage hardware having instructions stored thereon, the instructions, when carried out by a processing device, causing the processing device to perform operations of:

retrieving reconstruction data from a repository, the retrieved reconstruction data encoded in accordance with a tiered hierarchy including multiple available levels of quality in which portions of a signal are encoded;

transmitting the retrieved reconstruction data to a decoder, the decoder configured to reconstruct renditions of a signal based on the transmitted reconstruction data; and

during the transmission, varying a level of quality of the reconstruction data retrieved from the tiered hierarchy and transmitted to the decoder.

31. A computer system comprising:

a processor including processing hardware;

a hardware storage unit that stores instructions associated with an application executed by the processor; and

an interconnect coupling the processor and the hardware storage unit, causing the processing hardware to execute the application and perform operations of:

retrieving reconstruction data from a repository, the retrieved reconstruction data encoded in accordance with a tiered hierarchy including multiple available levels of quality in which portions of the signal are encoded;

transmitting the retrieved reconstruction data to a decoder, the decoder configured to reconstruct renditions of the signal based on the transmitted reconstruction data; and

during the transmission, varying a level of quality of the reconstruction data retrieved from the tiered hierarchy and transmitted to the decoder.