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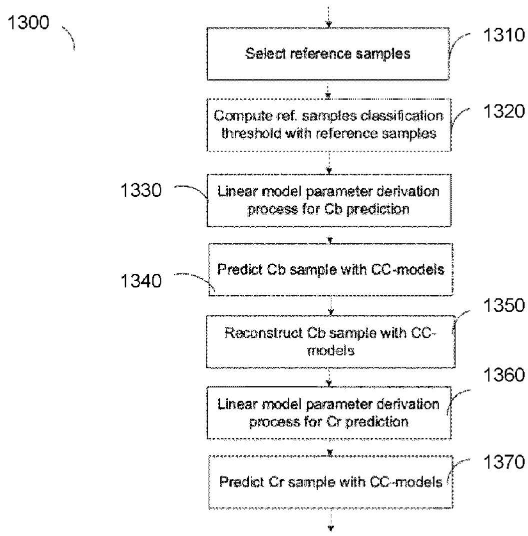

Second Chroma (Cr) samples prediction

FIG. 13

(57) **Abstract:** Systems, methods, and instrumentalities are disclosed for video encoding and/or decoding. A video encoding and/or decoding device may determine a second predicted chroma component sample value. The second predicted chroma component sample value may be determined based on a reconstructed first chroma component sample value and/or a first plurality of linear model parameters. A device may predict a second chroma component sample using the second predicted chroma component sample value to obtain a second predicted chroma component sample. The device may encode and/or decode a coding block using at least the second predicted chroma component sample.

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[Continued on next page]

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CROSS-COMPONENT INTRA PREDICTION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of European Provisional Patent Application No. 23306097.9, filed June 30, 2023, the contents of which are hereby incorporated by reference herein.

BACKGROUND

[0002] Video coding systems may be used to compress digital video signals, e.g., to reduce the storage and/or transmission bandwidth needed for such signals. Video coding systems may include, for example, block-based, wavelet-based, and/or object-based systems.

SUMMARY

[0003] Systems, methods, and instrumentalities are disclosed for video encoding. A video encoding device may include a processor configured to determine a second predicted chroma component sample value. The second predicted chroma component sample value may be determined based on a reconstructed first chroma component sample value and a first plurality of linear model parameters. A video encoding device may predict a second chroma component sample using the second predicted chroma component sample value to obtain a second predicted chroma component sample. A video encoding device may encode a coding block using at least the second predicted chroma component sample.

[0004] The video encoding device as described herein may include one or more features. For example, the video encoding device may determine the second predicted chroma component sample value based on a reconstructed luma sample value. For example, the video encoding device may determine a first predicted chroma component sample value, where the first predicted chroma component sample value may be determined based on a reconstructed luma sample value and a second plurality of linear model parameters.

[0005] For example, the video encoding device may predict a first chroma component sample using the first predicted chroma component sample value to obtain a first predicted chroma component sample. For example, the video encoding device may reconstruct the first chroma component sample using the first predicted chroma component sample to generate the reconstructed first chroma component sample value. For example, the second plurality of linear model parameters may include a first parameter associated with a luma sample, and a second parameter associated with a chroma sample value. For example, the first plurality of linear model parameters may include a first parameter associated with a luma sample value, a second parameter associated with a chroma sample value, and a third parameter is associated with biasing a linear model.

[0006] For example, the video encoding device may indicate, in video data, whether the second predicted chroma component sample value may be determined based on the reconstructed first chroma component sample value or the first predicted chroma component sample value. For example, the first plurality of linear model parameters and the second plurality of linear model parameters may be derived from a cross-component linear model (CCLM), a multi-model linear model (MMLM), or a convolutional cross-component model (CCCM). For example, the first plurality of linear model parameters or the second plurality of linear model parameters may be derived from a multi-model linear model (MMLM). For example, the video encoding device may determine a threshold to classify at least the reconstructed luma value.

[0007] A video decoding device may be provided. A video decoding device may be configured to determine a second predicted chroma component sample value, wherein the second predicted chroma component sample value may be determined based on a reconstructed first chroma component sample value and a first plurality of linear model parameters. A video decoding device may be configured to predict a second chroma component sample using the second predicted chroma component sample value to obtain a second predicted chroma component sample. A video decoding device may be configured to decode a coding block using at least the second predicted chroma component sample.

[0008] The video decoding device as described herein may include one or more features. For example, the video encoding device may determine the second predicted chroma component sample value based on a reconstructed luma sample value. For example, the video decoding device may determine a first predicted chroma component sample value. For example, the first predicted chroma component sample value may be determined based on a reconstructed luma sample value and a second plurality of linear model parameters. For example, the video decoding device may predict a first chroma component sample using the first predicted chroma component sample value to obtain a first predicted chroma component sample. For example, the video decoding device may reconstruct the first chroma component sample using the first predicted chroma component sample to generate the reconstructed first chroma component sample value. For example, the second plurality of linear model parameters may include a first parameter associated with a luma sample, and a second parameter associated with a chroma sample value.

[0009] For example, the first plurality of linear model parameters may include a first parameter associated with a luma sample value, a second parameter associated with a chroma sample value, and a third parameter is associated with biasing a linear model. For example, the video decoding device may indicate, in video data, whether the second predicted chroma component sample value may be determined based on the reconstructed first chroma component sample value or the first predicted chroma component sample value. For example, the first plurality of linear model parameters and/or the second plurality of linear model parameters may be derived from a cross-component linear model (CCLM), a multi-model linear model (MMLM), or a convolutional cross-component model (CCCM). For example, the first plurality of linear model parameters and/or the second plurality of linear model parameters may be derived from a multi-model linear model (MMLM). For example, the video decoding device may determine a threshold to classify at least the reconstructed luma value.

[0010] Systems, methods, and instrumentalities are disclosed for video encoding. A video encoding device may include a processor configured to determine a second predicted chroma component sample value. The second predicted chroma component sample value may be determined based on a reconstructed first chroma component sample value and a first plurality of linear model parameters. A video encoding device may predict a second chroma component sample using the second predicted chroma component sample value to obtain a second predicted chroma component sample. A video encoding device may encode a coding block using at least the second predicted chroma component sample.

[0011] The video encoding device as described herein may include one or more features. For example, the video encoding device may determine the second predicted chroma component sample value based on a reconstructed luma sample value. For example, the video encoding device may determine a first predicted chroma component sample value. The first predicted chroma component sample value may be determined based on a reconstructed luma sample value and a second plurality of linear model parameters. For example, the video encoding device may predict a first chroma component sample using the first predicted chroma component sample value to obtain a first predicted chroma component sample. For example, the video encoding device may reconstruct the first chroma component sample using the first predicted chroma component sample to generate the reconstructed first chroma component sample value.

[0012] For example, the second plurality of linear model parameters may include a first parameter associated with a luma sample, and a second parameter associated with a chroma sample value. For example, the first plurality of linear model parameters may include a first parameter associated with a luma sample value, a second parameter associated with a chroma sample value, and/or a third parameter associated with biasing a linear model. For example, the video encoding device may be further configured to indicate, in video data, whether the second predicted chroma component sample value may be determined based on the reconstructed first chroma component sample value or the first predicted chroma component sample value.

[0013] For example, the first plurality of linear model parameters and/or the second plurality of linear model parameters may be derived from a cross-component linear model (CCLM), a multi-model linear model (MMLM), or a convolutional cross-component model (CCCM).

[0014] For example, the first plurality of linear model parameters or the second plurality of linear model parameters may be derived from a multi-model linear model (MMLM). For example, the video encoding device may be further configured to determine a threshold to classify at least the reconstructed luma value.

[0015] A video decoding device may include a processor configured to determine a second predicted chroma component sample value. The second predicted chroma component sample value may be determined based on a reconstructed first chroma component sample value and a first plurality of linear model parameters. The video decoding device may predict a second chroma component sample using the second predicted chroma component sample value to obtain a second predicted chroma component sample. The video decoding device may decode a coding block using at least the second predicted chroma component sample.

[0016] The video decoding device may include one or more features. For example, the video decoding device may be configured to determine the second predicted chroma component sample value based on a reconstructed luma sample value. The video decoding device may determine a first predicted chroma component sample value. The first predicted chroma component sample value may be determined based on a reconstructed luma sample value and a second plurality of linear model parameters.

[0017] The video decoding device may predict a first chroma component sample using the first predicted chroma component sample value to obtain a first predicted chroma component sample. The video decoding device may reconstruct the first chroma component sample using the first predicted chroma component sample to generate the reconstructed first chroma component sample value. For example, the second plurality of linear model parameters may include a first parameter associated with a luma sample, and a second parameter associated with a chroma sample value.

[0018] For example, the first plurality of linear model parameters may include a first parameter associated with a luma sample value, a second parameter associated with a chroma sample value, and/or a third parameter associated with biasing a linear model. The video decoding device may indicate, in video data, whether the second predicted chroma component sample value may be determined based on the reconstructed first chroma component sample value or the first predicted chroma component sample value.

[0019] For example, the first plurality of linear model parameters and/or the second plurality of linear model parameters may be derived from a cross-component linear model (CCLM), a multi-model linear model (MMLM), or a convolutional cross-component model (CCCM).

[0020] For example, the first plurality of linear model parameters or the second plurality of linear model parameters may be derived from a multi-model linear model (MMLM). The video decoding device may be configured to determine a threshold to classify at least the reconstructed luma value.

[0021] Systems, methods, and instrumentalities described herein may involve a decoder. In some examples, the systems, methods, and instrumentalities described herein may involve an encoder. In some examples, the systems, methods, and instrumentalities described herein may involve a signal (e.g., from an encoder and/or received by a decoder). A computer-readable medium may include instructions for causing one or more processors to perform methods described herein. A computer program product may include instructions which, when the program is executed by one or more processors, may cause the one or more processors to carry out the methods described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] FIG. 1A is a system diagram illustrating an example communications system in which one or more disclosed embodiments may be implemented.

[0023] FIG. 1B is a system diagram illustrating an example wireless transmit/receive unit (WTRU) that may be used within the communications system illustrated in FIG. 1A according to an embodiment.

[0024] FIG. 1C is a system diagram illustrating an example radio access network (RAN) and an example core network (CN) that may be used within the communications system illustrated in FIG. 1A according to an embodiment.

[0025] FIG. 1D is a system diagram illustrating a further example RAN and a further example CN that may be used within the communications system illustrated in FIG. 1A according to an embodiment.

[0026] FIG. 2 illustrates an example video encoder.

[0027] FIG. 3 illustrates an example video decoder.

[0028] FIG. 4 illustrates an example of a system in which various aspects and examples may be implemented.

[0029] FIG. 5 illustrates example locations of one or more samples used for the derivation of α and β.

[0030] FIG. 6 illustrates an example of an effect of the slope adjustment parameter “u.”

[0031] FIG. 7 illustrates an example spatial part of a convolution filter.

[0032] FIG. 8 illustrates an example reference area (e.g., with its paddings) that may be used to derive the filter coefficients.

[0033] FIG. 9 illustrates an example spatial part of a gradient and location based convolutional cross-component model (GL-CCCM) convolutional filter.

[0034] FIG. 10 illustrates an example spatial part of a non-down sampled convolutional cross-component model (CCCM) luma terms that may be used for a convolutional filter.

[0035] FIG. 11 illustrates an example of possible positions of candidate regions.

[0036] FIG. 12 illustrates an example method for cross-component prediction.

[0037] FIG. 13 illustrates an example method for modifying a cross-component prediction when predicting Cb and Cr samples.

DETAILED DESCRIPTION

[0038] A more detailed understanding may be had from the following description, given by way of example in conjunction with the accompanying drawings.

[0039] FIG. 1A is a diagram illustrating an example communications system 100 in which one or more disclosed embodiments may be implemented. The communications system 100 may be a multiple access system that provides content, such as voice, data, video, messaging, broadcast, etc., to multiple wireless users. The communications system 100 may enable multiple wireless users to access such content through the sharing of system resources, including wireless bandwidth. For example, the communications systems 100 may employ one or more channel access methods, such as code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), orthogonal FDMA (OFDMA), single-carrier FDMA (SC-FDMA), zero-tail unique-word DFT-Spread OFDM (ZT UW DTS-s OFDM), unique word OFDM (UW-OFDM), resource block-filtered OFDM, filter bank multicarrier (FBMC), and the like.

[0040] As shown in FIG. 1A, the communications system 100 may include wireless transmit/receive units (WTRUs) 102a, 102b, 102c, 102d, a RAN 104/113, a CN 106/115, a public switched telephone network (PSTN) 108, the Internet 110, and other networks 112, though it will be appreciated that the disclosed embodiments contemplate any number of WTRUs, base stations, networks, and/or network elements. Each of the WTRUs 102a, 102b, 102c, 102d may be any type of device configured to operate and/or communicate in a wireless environment. By way of example, the WTRUs 102a, 102b, 102c, 102d, any of which may be referred to as a “station” and/or a “STA”, may be configured to transmit and/or receive wireless signals and may include a user equipment (UE), a mobile station, a fixed or mobile subscriber unit, a subscription-based unit, a pager, a cellular telephone, a personal digital assistant (PDA), a smartphone, a laptop, a netbook, a personal computer, a wireless sensor, a hotspot or Mi-Fi device, an Internet of Things (IoT) device, a watch or other wearable, a head-mounted display (HMD), a vehicle, a drone, a medical device and applications (e.g., remote surgery), an industrial device and applications (e.g., a robot and/or other wireless devices operating in an industrial and/or an automated processing chain contexts), a consumer electronics device, a device operating on commercial and/or industrial wireless networks, and the like. Any of the WTRUs 102a, 102b, 102c and 102d may be interchangeably referred to as a UE.

[0041] The communications systems 100 may also include a base station 114a and/or a base station 114b. Each of the base stations 114a, 114b may be any type of device configured to wirelessly interface with at least one of the WTRUs 102a, 102b, 102c, 102d to facilitate access to one or more communication networks, such as the CN 106/115, the Internet 110, and/or the other networks 112. By way of example, the base stations 114a, 114b may be a base transceiver station (BTS), a Node-B, an eNode B, a Home Node B, a Home eNode B, a gNB, a NR NodeB, a site controller, an access point (AP), a wireless router, and the like. While the base stations 114a, 114b are each depicted as a single element, it will be appreciated that the base stations 114a, 114b may include any number of interconnected base stations and/or network elements.

[0042] The base station 114a may be part of the RAN 104/113, which may also include other base stations and/or network elements (not shown), such as a base station controller (BSC), a radio network controller (RNC), relay nodes, etc. The base station 114a and/or the base station 114b may be configured to transmit and/or receive wireless signals on one or more carrier frequencies, which may be referred to as a cell (not shown). These frequencies may be in licensed spectrum, unlicensed spectrum, or a combination of licensed and unlicensed spectrum. A cell may provide coverage for a wireless service to a specific geographical area that may be relatively fixed or that may change over time. The cell may further be divided into cell sectors. For example, the cell associated with the base station 114a may be divided into three sectors. Thus, in one embodiment, the base station 114a may include three transceivers, i.e., one for each sector of the cell. In an embodiment, the base station 114a may employ multiple-input multiple output (MIMO) technology and may utilize multiple transceivers for each sector of the cell. For example, beamforming may be used to transmit and/or receive signals in desired spatial directions.

[0043] The base stations 114a, 114b may communicate with one or more of the WTRUs 102a, 102b, 102c, 102d over an air interface 116, which may be any suitable wireless communication link (e.g., radio frequency (RF), microwave, centimeter wave, micrometer wave, infrared (IR), ultraviolet (UV), visible light, etc.). The air interface 116 may be established using any suitable radio access technology (RAT).

[0044] More specifically, as noted above, the communications system 100 may be a multiple access system and may employ one or more channel access schemes, such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA, and the like. For example, the base station 114a in the RAN 104/113 and the WTRUs 102a, 102b, 102c may implement a radio technology such as Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access (UTRA), which may establish the air interface 115/116/117 using wideband CDMA (WCDMA). WCDMA may include communication protocols such as High-Speed Packet

Access (HSPA) and/or Evolved HSPA (HSPA+). HSPA may include High-Speed Downlink (DL) Packet Access (HSDPA) and/or High-Speed UL Packet Access (HSUPA).

[0045] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement a radio technology such as Evolved UMTS Terrestrial Radio Access (E-UTRA), which may establish the air interface 116 using Long Term Evolution (LTE) and/or LTE-Advanced (LTE-A) and/or LTE-Advanced Pro (LTE-A Pro).

[0046] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement a radio technology such as NR Radio Access , which may establish the air interface 116 using New Radio (NR).

[0047] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement multiple radio access technologies. For example, the base station 114a and the WTRUs 102a, 102b, 102c may implement LTE radio access and NR radio access together, for instance using dual connectivity (DC) principles. Thus, the air interface utilized by WTRUs 102a, 102b, 102c may be characterized by multiple types of radio access technologies and/or transmissions sent to/from multiple types of base stations (e.g., an eNB and a gNB).

[0048] In other embodiments, the base station 114a and the WTRUs 102a, 102b, 102c may implement radio technologies such as IEEE 802.11 (i.e., Wireless Fidelity (WiFi), IEEE 802.16 (i.e., Worldwide Interoperability for Microwave Access (WiMAX)), CDMA2000, CDMA2000 1X, CDMA2000 EV-DO, Interim Standard 2000 (IS-2000), Interim Standard 95 (IS-95), Interim Standard 856 (IS-856), Global System for Mobile communications (GSM), Enhanced Data rates for GSM Evolution (EDGE), GSM EDGE (GERAN), and the like.

[0049] The base station 114b in FIG. 1A may be a wireless router, Home Node B, Home eNode B, or access point, for example, and may utilize any suitable RAT for facilitating wireless connectivity in a localized area, such as a place of business, a home, a vehicle, a campus, an industrial facility, an air corridor (e.g., for use by drones), a roadway, and the like. In one embodiment, the base station 114b and the WTRUs 102c, 102d may implement a radio technology such as IEEE 802.11 to establish a wireless local area network (WLAN). In an embodiment, the base station 114b and the WTRUs 102c, 102d may implement a radio technology such as IEEE 802.15 to establish a wireless personal area network (WPAN). In yet another embodiment, the base station 114b and the WTRUs 102c, 102d may utilize a cellular-based RAT (e.g., WCDMA, CDMA2000, GSM, LTE, LTE-A, LTE-A Pro, NR etc.) to establish a picocell or femtocell. As shown in FIG. 1A, the base station 114b may have a direct connection to the Internet 110. Thus, the base station 114b may not be required to access the Internet 110 via the CN 106/115.

[0050] The RAN 104/113 may be in communication with the CN 106/115, which may be any type of network configured to provide voice, data, applications, and/or voice over internet protocol (VoIP) services to one or more of the WTRUs 102a, 102b, 102c, 102d. The data may have varying quality of service (QoS) requirements, such as differing throughput requirements, latency requirements, error tolerance requirements, reliability requirements, data throughput requirements, mobility requirements, and the like. The CN 106/115 may provide call control, billing services, mobile location-based services, pre-paid calling, Internet connectivity, video distribution, etc., and/or perform high-level security functions, such as user authentication. Although not shown in FIG. 1A, it will be appreciated that the RAN 104/113 and/or the CN 106/115 may be in direct or indirect communication with other RANs that employ the same RAT as the RAN 104/113 or a different RAT. For example, in addition to being connected to the RAN 104/113, which may be utilizing a NR radio technology, the CN 106/115 may also be in communication with another RAN (not shown) employing a GSM, UMTS, CDMA 2000, WiMAX, E-UTRA, or WiFi radio technology.

[0051] The CN 106/115 may also serve as a gateway for the WTRUs 102a, 102b, 102c, 102d to access the PSTN 108, the Internet 110, and/or the other networks 112. The PSTN 108 may include circuit-switched telephone networks that provide plain old telephone service (POTS). The Internet 110 may include a global system of interconnected computer networks and devices that use common communication protocols, such as the transmission control protocol (TCP), user datagram protocol (UDP) and/or the internet protocol (IP) in the TCP/IP internet protocol suite. The networks 112 may include wired and/or wireless communications networks owned and/or operated by other service providers. For example, the networks 112 may include another CN connected to one or more RANs, which may employ the same RAT as the RAN 104/113 or a different RAT.

[0052] Some or all of the WTRUs 102a, 102b, 102c, 102d in the communications system 100 may include multi-mode capabilities (e.g., the WTRUs 102a, 102b, 102c, 102d may include multiple transceivers for communicating with different wireless networks over different wireless links). For example, the WTRU 102c shown in FIG. 1A may be configured to communicate with the base station 114a, which may employ a cellular-based radio technology, and with the base station 114b, which may employ an IEEE 802 radio technology.

[0053] FIG. 1B is a system diagram illustrating an example WTRU 102. As shown in FIG. 1B, the WTRU 102 may include a processor 118, a transceiver 120, a transmit/receive element 122, a speaker/microphone 124, a keypad 126, a display/touchpad 128, non-removable memory 130, removable memory 132, a power source 134, a global positioning system (GPS) chipset 136, and/or other peripherals 138, among others. It will be appreciated that the WTRU 102 may include any sub-combination of the foregoing elements while remaining consistent with an embodiment.

[0054] The processor 118 may be a general purpose processor, a special purpose processor, a conventional processor, a digital signal processor (DSP), a plurality of microprocessors, one or more microprocessors in association with a DSP core, a controller, a microcontroller, Application Specific

Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs) circuits, any other type of integrated circuit (IC), a state machine, and the like. The processor 118 may perform signal coding, data processing, power control, input/output processing, and/or any other functionality that enables the WTRU 102 to operate in a wireless environment. The processor 118 may be coupled to the transceiver 120, which may be coupled to the transmit/receive element 122. While FIG. 1B depicts the processor 118 and the transceiver 120 as separate components, it will be appreciated that the processor 118 and the transceiver 120 may be integrated together in an electronic package or chip.

[0055] The transmit/receive element 122 may be configured to transmit signals to, or receive signals from, a base station (e.g., the base station 114a) over the air interface 116. For example, in one embodiment, the transmit/receive element 122 may be an antenna configured to transmit and/or receive RF signals. In an embodiment, the transmit/receive element 122 may be an emitter/detector configured to transmit and/or receive IR, UV, or visible light signals, for example. In yet another embodiment, the transmit/receive element 122 may be configured to transmit and/or receive both RF and light signals. It will be appreciated that the transmit/receive element 122 may be configured to transmit and/or receive any combination of wireless signals.

[0056] Although the transmit/receive element 122 is depicted in FIG. 1B as a single element, the WTRU 102 may include any number of transmit/receive elements 122. More specifically, the WTRU 102 may employ MIMO technology. Thus, in one embodiment, the WTRU 102 may include two or more transmit/receive elements 122 (e.g., multiple antennas) for transmitting and receiving wireless signals over the air interface 116.

[0057] The transceiver 120 may be configured to modulate the signals that are to be transmitted by the transmit/receive element 122 and to demodulate the signals that are received by the transmit/receive element 122. As noted above, the WTRU 102 may have multi-mode capabilities. Thus, the transceiver 120 may include multiple transceivers for enabling the WTRU 102 to communicate via multiple RATs, such as NR and IEEE 802.11, for example.

[0058] The processor 118 of the WTRU 102 may be coupled to, and may receive user input data from, the speaker/microphone 124, the keypad 126, and/or the display/touchpad 128 (e.g., a liquid crystal display (LCD) display unit or organic light-emitting diode (OLED) display unit). The processor 118 may also output user data to the speaker/microphone 124, the keypad 126, and/or the display/touchpad 128. In addition, the processor 118 may access information from, and store data in, any type of suitable memory, such as the non-removable memory 130 and/or the removable memory 132. The non-removable memory 130 may include random-access memory (RAM), read-only memory (ROM), a hard disk, or any other type of memory storage device. The removable memory 132 may include a subscriber identity module (SIM) card, a memory stick, a secure digital (SD) memory card, and the like. In other embodiments, the processor 118 may access information from, and store data in, memory that is not physically located on the WTRU 102, such as on a server or a home computer (not shown).

[0059] The processor 118 may receive power from the power source 134, and may be configured to distribute and/or control the power to the other components in the WTRU 102. The power source 134 may be any suitable device for powering the WTRU 102. For example, the power source 134 may include one or more dry cell batteries (e.g., nickel-cadmium (NiCd), nickel-zinc (NiZn), nickel metal hydride (NiMH), lithium-ion (Li-ion), etc.), solar cells, fuel cells, and the like.

[0060] The processor 118 may also be coupled to the GPS chipset 136, which may be configured to provide location information (e.g., longitude and latitude) regarding the current location of the WTRU 102. In addition to, or in lieu of, the information from the GPS chipset 136, the WTRU 102 may receive location information over the air interface 116 from a base station (e.g., base stations 114a, 114b) and/or determine its location based on the timing of the signals being received from two or more nearby base stations. It will be appreciated that the WTRU 102 may acquire location information by way of any suitable location-determination method while remaining consistent with an embodiment.

[0061] The processor 118 may further be coupled to other peripherals 138, which may include one or more software and/or hardware modules that provide additional features, functionality and/or wired or wireless connectivity. For example, the peripherals 138 may include an accelerometer, an e-compass, a satellite transceiver, a digital camera (for photographs and/or video), a universal serial bus (USB) port, a vibration device, a television transceiver, a hands free headset, a Bluetooth® module, a frequency modulated (FM) radio unit, a digital music player, a media player, a video game player module, an Internet browser, a Virtual Reality and/or Augmented Reality (VR/AR) device, an activity tracker, and the like. The peripherals 138 may include one or more sensors, the sensors may be one or more of a gyroscope, an accelerometer, a hall effect sensor, a magnetometer, an orientation sensor, a proximity sensor, a temperature sensor, a time sensor; a geolocation sensor; an altimeter, a light sensor, a touch sensor, a magnetometer, a barometer, a gesture sensor, a biometric sensor, and/or a humidity sensor.

[0062] The WTRU 102 may include a full duplex radio for which transmission and reception of some or all of the signals (e.g., associated with particular subframes for both the UL (e.g., for transmission) and downlink (e.g., for reception) may be concurrent and/or simultaneous. The full duplex radio may include an interference management unit to reduce and or substantially eliminate self-interference via either hardware (e.g., a choke) or signal processing via a processor (e.g., a separate processor (not shown) or via processor 118). In an embodiment, the WTRU 102 may include a half-duplex radio for which transmission and reception of some or all of the signals (e.g., associated with particular subframes for either the UL (e.g., for transmission) or the downlink (e.g., for reception)).

[0063] FIG. 1C is a system diagram illustrating the RAN 104 and the CN 106 according to an embodiment. As noted above, the RAN 104 may employ an E-UTRA radio technology to communicate with the WTRUs 102a, 102b, 102c over the air interface 116. The RAN 104 may also be in communication with the CN 106.

[0064] The RAN 104 may include eNode-Bs 160a, 160b, 160c, though it will be appreciated that the RAN 104 may include any number of eNode-Bs while remaining consistent with an embodiment. The eNode-Bs 160a, 160b, 160c may each include one or more transceivers for communicating with the WTRUs 102a, 102b, 102c over the air interface 116. In one embodiment, the eNode-Bs 160a, 160b, 160c may implement MIMO technology. Thus, the eNode-B 160a, for example, may use multiple antennas to transmit wireless signals to, and/or receive wireless signals from, the WTRU 102a.

[0065] Each of the eNode-Bs 160a, 160b, 160c may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the UL and/or DL, and the like. As shown in FIG. 1C, the eNode-Bs 160a, 160b, 160c may communicate with one another over an X2 interface.

[0066] The CN 106 shown in FIG. 1C may include a mobility management entity (MME) 162, a serving gateway (SGW) 164, and a packet data network (PDN) gateway (or PGW) 166. While each of the foregoing elements are depicted as part of the CN 106, it will be appreciated that any of these elements may be owned and/or operated by an entity other than the CN operator.

[0067] The MME 162 may be connected to each of the eNode-Bs 162a, 162b, 162c in the RAN 104 via an S1 interface and may serve as a control node. For example, the MME 162 may be responsible for authenticating users of the WTRUs 102a, 102b, 102c, bearer activation/deactivation, selecting a particular serving gateway during an initial attach of the WTRUs 102a, 102b, 102c, and the like. The MME 162 may provide a control plane function for switching between the RAN 104 and other RANs (not shown) that employ other radio technologies, such as GSM and/or WCDMA.

[0068] The SGW 164 may be connected to each of the eNode Bs 160a, 160b, 160c in the RAN 104 via the S1 interface. The SGW 164 may generally route and forward user data packets to/from the WTRUs 102a, 102b, 102c. The SGW 164 may perform other functions, such as anchoring user planes during inter-eNode B handovers, triggering paging when DL data is available for the WTRUs 102a, 102b, 102c, managing and storing contexts of the WTRUs 102a, 102b, 102c, and the like.

[0069] The SGW 164 may be connected to the PGW 166, which may provide the WTRUs 102a, 102b, 102c with access to packet-switched networks, such as the Internet 110, to facilitate communications between the WTRUs 102a, 102b, 102c and IP-enabled devices.

[0070] The CN 106 may facilitate communications with other networks. For example, the CN 106 may provide the WTRUs 102a, 102b, 102c with access to circuit-switched networks, such as the PSTN 108, to facilitate communications between the WTRUs 102a, 102b, 102c and traditional land-line communications devices. For example, the CN 106 may include, or may communicate with, an IP gateway (e.g., an IP multimedia subsystem (IMS) server) that serves as an interface between the CN 106 and the PSTN 108. In addition, the CN 106 may provide the WTRUs 102a, 102b, 102c with access to the other networks 112, which may include other wired and/or wireless networks that are owned and/or operated by other service providers.

[0071] Although the WTRU is described in FIGS. 1A-1D as a wireless terminal, it is contemplated that in certain representative embodiments that such a terminal may use (e.g., temporarily or permanently) wired communication interfaces with the communication network.

[0072] In representative embodiments, the other network 112 may be a WLAN.

[0073] A WLAN in Infrastructure Basic Service Set (BSS) mode may have an Access Point (AP) for the BSS and one or more stations (STAs) associated with the AP. The AP may have an access or an interface to a Distribution System (DS) or another type of wired/wireless network that carries traffic in to and/or out of the BSS. Traffic to STAs that originates from outside the BSS may arrive through the AP and may be delivered to the STAs. Traffic originating from STAs to destinations outside the BSS may be sent to the AP to be delivered to respective destinations. Traffic between STAs within the BSS may be sent through the AP, for example, where the source STA may send traffic to the AP and the AP may deliver the traffic to the destination STA. The traffic between STAs within a BSS may be considered and/or referred to as peer-to-peer traffic. The peer-to-peer traffic may be sent between (e.g., directly between) the source and destination STAs with a direct link setup (DLS). In certain representative embodiments, the DLS may use an 802.11e DLS or an 802.11z tunneled DLS (TDLS). A WLAN using an Independent BSS (IBSS) mode may not have an AP, and the STAs (e.g., all of the STAs) within or using the IBSS may communicate directly with each other. The IBSS mode of communication may sometimes be referred to herein as an “ad-hoc” mode of communication.

[0074] When using the 802.11ac infrastructure mode of operation or a similar mode of operations, the AP may transmit a beacon on a fixed channel, such as a primary channel. The primary channel may be a fixed width (e.g., 20 MHz wide bandwidth) or a dynamically set width via signaling. The primary channel may be the operating channel of the BSS and may be used by the STAs to establish a connection with the AP. In certain representative embodiments, Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) may be implemented, for example in in 802.11 systems. For CSMA/CA, the STAs (e.g., every STA), including the AP, may sense the primary channel. If the primary channel is sensed/detected and/or determined to be busy by a particular STA, the particular STA may back off. One STA (e.g., only one station) may transmit at any given time in a given BSS.

[0075] High Throughput (HT) STAs may use a 40 MHz wide channel for communication, for example, via a combination of the primary 20 MHz channel with an adjacent or nonadjacent 20 MHz channel to form a 40 MHz wide channel.

[0076] Very High Throughput (VHT) STAs may support 20MHz, 40 MHz, 80 MHz, and/or 160 MHz wide channels. The 40 MHz, and/or 80 MHz, channels may be formed by combining contiguous 20 MHz channels. A 160 MHz channel may be formed by combining 8 contiguous 20 MHz channels, or by combining two non-contiguous 80 MHz channels, which may be referred to as an 80+80 configuration. For the 80+80 configuration, the data, after channel encoding, may be passed through a segment parser that may divide the data into two streams. Inverse Fast Fourier Transform (IFFT) processing, and time domain processing, may be done on each stream separately. The streams may be mapped on to the two 80 MHz channels, and the data may be transmitted by a transmitting STA. At the receiver of the receiving STA, the above described operation for the 80+80 configuration may be reversed, and the combined data may be sent to the Medium Access Control (MAC).

[0077] Sub 1 GHz modes of operation are supported by 802.11af and 802.11ah. The channel operating bandwidths, and carriers, are reduced in 802.11af and 802.11ah relative to those used in 802.11n, and 802.11ac. 802.11af supports 5 MHz, 10 MHz and 20 MHz bandwidths in the TV White Space (TVWS) spectrum, and 802.11ah supports 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz bandwidths using non-TVWS spectrum. According to a representative embodiment, 802.11ah may support Meter Type Control/Machine-Type Communications, such as MTC devices in a macro coverage area. MTC devices may have certain capabilities, for example, limited capabilities including support for (e.g., only support for) certain and/or limited bandwidths. The MTC devices may include a battery with a battery life above a threshold (e.g., to maintain a very long battery life).

[0078] WLAN systems, which may support multiple channels, and channel bandwidths, such as 802.11n, 802.11ac, 802.11af, and 802.11ah, include a channel which may be designated as the primary channel. The primary channel may have a bandwidth equal to the largest common operating bandwidth supported by all STAs in the BSS. The bandwidth of the primary channel may be set and/or limited by a STA, from among all STAs in operating in a BSS, which supports the smallest bandwidth operating mode. In the example of 802.11ah, the primary channel may be 1 MHz wide for STAs (e.g., MTC type devices) that support (e.g., only support) a 1 MHz mode, even if the AP, and other STAs in the BSS support 2 MHz, 4 MHz, 8 MHz, 16 MHz, and/or other channel bandwidth operating modes. Carrier sensing and/or Network Allocation Vector (NAV) settings may depend on the status of the primary channel. If the primary channel is busy, for example, due to a STA (which supports only a 1 MHz operating mode), transmitting to the AP, the entire available frequency bands may be considered busy even though a majority of the frequency bands remains idle and may be available.

[0079] In the United States, the available frequency bands, which may be used by 802.11ah, are from 902 MHz to 928 MHz. In Korea, the available frequency bands are from 917.5 MHz to 923.5 MHz. In Japan, the available frequency bands are from 916.5 MHz to 927.5 MHz. The total bandwidth available for 802.11ah is 6 MHz to 26 MHz depending on the country code.

[0080] FIG. 1D is a system diagram illustrating the RAN 113 and the CN 115 according to an embodiment. As noted above, the RAN 113 may employ an NR radio technology to communicate with the WTRUs 102a, 102b, 102c over the air interface 116. The RAN 113 may also be in communication with the CN 115.

[0081] The RAN 113 may include gNBs 180a, 180b, 180c, though it will be appreciated that the RAN 113 may include any number of gNBs while remaining consistent with an embodiment. The gNBs 180a, 180b, 180c may each include one or more transceivers for communicating with the WTRUs 102a, 102b, 102c over the air interface 116. In one embodiment, the gNBs 180a, 180b, 180c may implement MIMO technology. For example, gNBs 180a, 108b may utilize beamforming to transmit signals to and/or receive signals from the gNBs 180a, 180b, 180c. Thus, the gNB 180a, for example, may use multiple antennas to transmit wireless signals to, and/or receive wireless signals from, the WTRU 102a. In an embodiment, the gNBs 180a, 180b, 180c may implement carrier aggregation technology. For example, the gNB 180a may transmit multiple component carriers to the WTRU 102a (not shown). A subset of these component carriers may be on unlicensed spectrum while the remaining component carriers may be on licensed spectrum. In an embodiment, the gNBs 180a, 180b, 180c may implement Coordinated Multi-Point (CoMP) technology. For example, WTRU 102a may receive coordinated transmissions from gNB 180a and gNB 180b (and/or gNB 180c).

[0082] The WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using transmissions associated with a scalable numerology. For example, the OFDM symbol spacing and/or OFDM subcarrier spacing may vary for different transmissions, different cells, and/or different portions of the wireless transmission spectrum. The WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using subframe or transmission time intervals (TTIs) of various or scalable lengths (e.g., containing varying number of OFDM symbols and/or lasting varying lengths of absolute time).

[0083] The gNBs 180a, 180b, 180c may be configured to communicate with the WTRUs 102a, 102b, 102c in a standalone configuration and/or a non-standalone configuration. In the standalone configuration, WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c without also accessing other RANs (e.g., such as eNode-Bs 160a, 160b, 160c). In the standalone configuration, WTRUs 102a, 102b, 102c may utilize one or more of gNBs 180a, 180b, 180c as a mobility anchor point. In the standalone configuration, WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using signals in an unlicensed band. In a non-standalone configuration WTRUs 102a, 102b, 102c may communicate with/connect to gNBs 180a, 180b, 180c while also communicating with/connecting to another RAN such as eNode-Bs 160a, 160b, 160c. For example, WTRUs 102a, 102b, 102c may implement DC principles to communicate with one or more gNBs 180a, 180b, 180c and one or more eNode-Bs 160a, 160b, 160c substantially simultaneously. In the non-standalone configuration, eNode-Bs 160a, 160b, 160c may serve as a mobility anchor for WTRUs 102a, 102b, 102c and gNBs 180a, 180b, 180c may provide additional coverage and/or throughput for servicing WTRUs 102a, 102b, 102c.

[0084] Each of the gNBs 180a, 180b, 180c may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the UL and/or DL, support of network slicing, dual connectivity, interworking between NR and E-UTRA, routing of user plane data towards User Plane Function (UPF) 184a, 184b, routing of control plane information towards Access and Mobility Management Function (AMF) 182a, 182b and the like. As shown in FIG. 1D, the gNBs 180a, 180b, 180c may communicate with one another over an Xn interface.

[0085] The CN 115 shown in FIG. 1D may include at least one AMF 182a, 182b, at least one UPF 184a,184b, at least one Session Management Function (SMF) 183a, 183b, and possibly a Data Network (DN) 185a, 185b. While each of the foregoing elements are depicted as part of the CN 115, it will be appreciated that any of these elements may be owned and/or operated by an entity other than the CN operator.

[0086] The AMF 182a, 182b may be connected to one or more of the gNBs 180a, 180b, 180c in the RAN 113 via an N2 interface and may serve as a control node. For example, the AMF 182a, 182b may be responsible for authenticating users of the WTRUs 102a, 102b, 102c, support for network slicing (e.g., handling of different PDU sessions with different requirements), selecting a particular SMF 183a, 183b, management of the registration area, termination of NAS signaling, mobility management, and the like. Network slicing may be used by the AMF 182a, 182b in order to customize CN support for WTRUs 102a, 102b, 102c based on the types of services being utilized WTRUs 102a, 102b, 102c. For example, different network slices may be established for different use cases such as services relying on ultra-reliable low latency (URLLC) access, services relying on enhanced massive mobile broadband (eMBB) access, services for machine type communication (MTC) access, and/or the like. The AMF 182a, 182b may provide a control plane function for switching between the RAN 113 and other RANs (not shown) that employ other radio technologies, such as LTE, LTE-A, LTE-A Pro, and/or non-3GPP access technologies such as WiFi.

[0087] The SMF 183a, 183b may be connected to an AMF 182a, 182b in the CN 115 via an N11 interface. The SMF 183a, 183b may also be connected to a UPF 184a, 184b in the CN 115 via an N4 interface. The SMF 183a, 183b may select and control the UPF 184a, 184b and configure the routing of traffic through the UPF 184a, 184b. The SMF 183a, 183b may perform other functions, such as managing and allocating UE IP address, managing PDU sessions, controlling policy enforcement and QoS, providing downlink data notifications, and the like. A PDU session type may be IP-based, non-IP based, Ethernet-based, and the like.

[0088] The UPF 184a, 184b may be connected to one or more of the gNBs 180a, 180b, 180c in the RAN 113 via an N3 interface, which may provide the WTRUs 102a, 102b, 102c with access to packet-switched networks, such as the Internet 110, to facilitate communications between the WTRUs 102a, 102b, 102c and IP-enabled devices. The UPF 184, 184b may perform other functions, such as routing and forwarding packets, enforcing user plane policies, supporting multi-homed PDU sessions, handling user plane QoS, buffering downlink packets, providing mobility anchoring, and the like.

[0089] The CN 115 may facilitate communications with other networks. For example, the CN 115 may include, or may communicate with, an IP gateway (e.g., an IP multimedia subsystem (IMS) server) that serves as an interface between the CN 115 and the PSTN 108. In addition, the CN 115 may provide the WTRUs 102a, 102b, 102c with access to the other networks 112, which may include other wired and/or wireless networks that are owned and/or operated by other service providers. In one embodiment, the WTRUs 102a, 102b, 102c may be connected to a local Data Network (DN) 185a, 185b through the UPF 184a, 184b via the N3 interface to the UPF 184a, 184b and an N6 interface between the UPF 184a, 184b and the DN 185a, 185b.

[0090] In view of Figures 1A-1D, and the corresponding description of Figures 1A-1D, one or more, or all, of the functions described herein with regard to one or more of: WTRU 102a-d, Base Station 114a-b, eNode-B 160a-c, MME 162, SGW 164, PGW 166, gNB 180a-c, AMF 182a-b, UPF 184a-b, SMF 183a-b, DN 185a-b, and/or any other device(s) described herein, may be performed by one or more emulation devices (not shown). The emulation devices may be one or more devices configured to emulate one or more, or all, of the functions described herein. For example, the emulation devices may be used to test other devices and/or to simulate network and/or WTRU functions.

[0091] The emulation devices may be designed to implement one or more tests of other devices in a lab environment and/or in an operator network environment. For example, the one or more emulation devices may perform the one or more, or all, functions while being fully or partially implemented and/or deployed as part of a wired and/or wireless communication network in order to test other devices within the communication network. The one or more emulation devices may perform the one or more, or all, functions while being temporarily implemented/deployed as part of a wired and/or wireless communication network. The emulation device may be directly coupled to another device for purposes of testing and/or may perform testing using over-the-air wireless communications.

[0092] The one or more emulation devices may perform the one or more, including all, functions while not being implemented/deployed as part of a wired and/or wireless communication network. For example, the emulation devices may be utilized in a testing scenario in a testing laboratory and/or a non-deployed (e.g., testing) wired and/or wireless communication network in order to implement testing of one or more components. The one or more emulation devices may be testing equipment. Direct RF coupling and/or wireless communications via RF circuitry (e.g., which may include one or more antennas) may be used by the emulation devices to transmit and/or receive data.

[0093] This application describes a variety of aspects, including tools, features, examples, models, approaches, etc. Many of these aspects are described with specificity and, at least to show the individual characteristics, are often described in a manner that may sound limiting. However, this is for purposes of clarity in description, and does not limit the application or scope of those aspects. Indeed, all of the different aspects may be combined and interchanged to provide further aspects. Moreover, the aspects may be combined and interchanged with aspects described in earlier filings as well.

[0094] The aspects described and contemplated in this application may be implemented in many different forms. FIGS. 5-13 described herein may provide some examples, but other examples are contemplated. The discussion of FIGS. 5-13 does not limit the breadth of the implementations. At least one of the aspects generally relates to video encoding and decoding, and at least one other aspect generally relates to transmitting a bitstream generated or encoded. These and other aspects may be implemented as a method, an apparatus, a computer readable storage medium having stored thereon instructions for encoding or decoding video data according to any of the methods described, and/or a computer readable storage medium having stored thereon a bitstream generated according to any of the methods described.

[0095] In the present application, the terms “reconstructed” and “decoded” may be used interchangeably, the terms “pixel” and “sample” may be used interchangeably, the terms “image,” “picture” and “frame” may be used interchangeably.

[0096] Various methods are described herein, and each of the methods comprises one or more steps or actions for achieving the described method. Unless a specific order of steps or actions is required for proper operation of the method, the order and/or use of specific steps and/or actions may be modified or combined. Additionally, terms such as “first”, “second”, etc. may be used in various examples to modify an element, component, step, operation, etc., such as, for example, a “first decoding” and a “second decoding”. Use of such terms does not imply an ordering to the modified operations unless specifically required. So, in this example, the first decoding need not be performed before the second decoding, and may occur, for example, before, during, or in an overlapping time period with the second decoding.

[0097] Various methods and other aspects described in this application may be used to modify modules, for example, decoding modules, of a video encoder 200 and decoder 300 as shown in FIG. 2 and FIG. 3. Moreover, the subject matter disclosed herein may be applied, for example, to any type, format or version of video coding, whether described in a standard or a recommendation, whether pre-existing or futuredeveloped, and extensions of any such standards and recommendations. Unless indicated otherwise, or technically precluded, the aspects described in this application may be used individually or in combination.

[0098] Various numeric values are used in examples described the present application, such as reconstructed luma and chroma sample values, etc. These and other specific values are for purposes of describing examples and the aspects described are not limited to these specific values.

[0099] FIG. 2 is a diagram showing an example video encoder. Variations of example encoder 200 are contemplated, but the encoder 200 is described below for purposes of clarity without describing all expected variations.

[0100] Before being encoded, the video sequence may go through pre-encoding processing (201), for example, applying a color transform to the input color picture (e.g., conversion from RGB 4:4:4 to YCbCr 4:2:0), or performing a remapping of the input picture components in order to get a signal distribution more resilient to compression (for instance using a histogram equalization of one of the color components). Metadata can be associated with the pre-processing and attached to the bitstream. In the encoder 200, a picture is encoded by the encoder elements as described below. The picture to be encoded is partitioned (202) and processed in units of, for example, CUs (Coding Units). Each unit is encoded using, for example, either an intra or inter mode. When a unit is encoded in an intra mode, it performs intra prediction (260). In an inter mode, motion estimation (275) and compensation (270) are performed. The encoder decides (205) which one of the intra mode or inter mode to use for encoding the unit, and indicates the intra/inter decision by, for example, a prediction mode flag. Prediction residuals are calculated, for example, by subtracting (210) the predicted block from the original image block. The prediction residuals are then transformed (225) and quantized (230). The quantized transform coefficients, as well as motion vectors and other syntax elements such as the picture partitioning information, are entropy coded (245) to output a bitstream. The encoder can skip the transform and apply quantization directly to the non-transformed residual signal. The encoder can bypass both transform and quantization, i.e., the residual is coded directly without the application of the transform or quantization processes.

[0101] The encoder decodes an encoded block to provide a reference for further predictions. The quantized transform coefficients are de-quantized (240), and inverse transformed (250) to decode prediction residuals. Combining (255) the decoded prediction residuals and the predicted block, an image block is reconstructed. In-loop filters (265) are applied to the reconstructed picture to perform, for example, deblocking/SAO (Sample Adaptive Offset)/ALF (Adaptive Loop Filter) filtering to reduce encoding artifacts. The filtered image is stored in a reference picture buffer (280). FIG. 3 is a diagram showing an example of a video decoder. In example decoder 300, a bitstream is decoded by the decoder elements as described below. Video decoder 300 generally performs a decoding pass reciprocal to the encoding pass as described in FIG. 2. The encoder 200 also generally performs video decoding as part of encoding video data.

[0102] In particular, the input of the decoder includes a video bitstream, which can be generated by video encoder 200. The bitstream is first entropy decoded (330) to obtain transform coefficients, prediction modes, motion vectors, and other coded information. The picture partition information indicates how the picture is partitioned. The decoder may therefore divide (335) the picture according to the decoded picture partitioning information. The transform coefficients are de-quantized (340), and inverse transformed (350) to decode the prediction residuals. Combining (355) the decoded prediction residuals and the predicted block, an image block is reconstructed. The predicted block can be obtained (370) from intra prediction (360) or motion-compensated prediction (i.e., inter prediction) (375). In-loop filters (365) are applied to the reconstructed image. The filtered image is stored at a reference picture buffer (380). Note that, for a given picture, the contents of the reference picture buffer 380 on the decoder 300 side is identical to the contents of the reference picture buffer 280 on the encoder 200 side for the same picture. The decoded picture can further go through post-decoding processing (385), for example, an inverse color transform (e.g., conversion from YCbCr 4:2:0 to RGB 4:4:4) or an inverse remapping performing the inverse of the remapping process performed in the pre-encoding processing (201). The post-decoding processing can use metadata derived in the pre-encoding processing and signaled in the bitstream. FIG. 4A is a diagram showing an example of a system in which various aspects and examples described herein may be implemented. System 400 may be embodied as a device including the various components described below and is configured to perform one or more of the aspects described in this document. Examples of such devices, include, but are not limited to, various electronic devices such as personal computers, laptop computers, smartphones, tablet computers, digital multimedia set top boxes, digital television receivers, personal video recording systems, connected home appliances, and servers. Elements of system 400, singly or in combination, may be embodied in a single integrated circuit (IC), multiple ICs, and/or discrete components. For example, in at least one example, the processing and encoder/decoder elements of system 400 are distributed across multiple ICs and/or discrete components. In various examples, the system 400 is communicatively coupled to one or more other systems, or other electronic devices, via, for example, a communications bus or through dedicated input and/or output ports. In various examples, the system 400 is configured to implement one or more of the aspects described in this document.

[0103] The system 400 includes at least one processor 410 configured to execute instructions loaded therein for implementing, for example, the various aspects described in this document. Processor 410 can include embedded memory, input output interface, and various other circuitries as known in the art. The system 400 includes at least one memory 420 (e.g., a volatile memory device, and/or a non-volatile memory device). System 400 includes a storage device 440, which can include non-volatile memory and/or volatile memory, including, but not limited to, Electrically Erasable Programmable Read-Only Memory (EEPROM), Read-Only Memory (ROM), Programmable Read-Only Memory (PROM), Random Access Memory (RAM), Dynamic Random Access Memory (DRAM), Static Random Access Memory (SRAM), flash, magnetic disk drive, and/or optical disk drive. The storage device 440 can include an internal storage device, an attached storage device (including detachable and non-detachable storage devices), and/or a network accessible storage device, as non-limiting examples.

[0104] System 400 includes an encoder/decoder module 430 configured, for example, to process data to provide an encoded video or decoded video, and the encoder/decoder module 430 can include its own processor and memory. The encoder/decoder module 430 represents module(s) that may be included in a device to perform the encoding and/or decoding functions. As is known, a device can include one or both of the encoding and decoding modules. Additionally, encoder/decoder module 430 may be implemented as a separate element of system 400 or may be incorporated within processor 410 as a combination of hardware and software as known to those skilled in the art.

[0105] Program code to be loaded onto processor 410 or encoder/decoder 430 to perform the various aspects described in this document may be stored in storage device 440 and subsequently loaded onto memory 420 for execution by processor 410. In accordance with various examples, one or more of processor 410, memory 420, storage device 440, and encoder/decoder module 430 can store one or more of various items during the performance of the processes described in this document. Such stored items can include, but are not limited to, the input video, the decoded video or portions of the decoded video, the bitstream, matrices, variables, and intermediate or final results from the processing of equations, formulas, operations, and operational logic.

[0106] In some examples, memory inside of the processor 410 and/or the encoder/decoder module 430 is used to store instructions and to provide working memory for processing that is needed during encoding or decoding. In other examples, however, a memory external to the processing device (for example, the processing device may be either the processor 410 or the encoder/decoder module 430) is used for one or more of these functions. The external memory may be the memory 420 and/or the storage device 440, for example, a dynamic volatile memory and/or a non-volatile flash memory. In several examples, an external non-volatile flash memory is used to store the operating system of, for example, a television. In at least one example, a fast external dynamic volatile memory such as a RAM is used as working memory for video encoding and decoding operations.

[0107] The input to the elements of system 400 may be provided through various input devices as indicated in block 445. Such input devices include, but are not limited to, (i) a radio frequency (RF) portion that receives an RF signal transmitted, for example, over the air by a broadcaster, (ii) a Component (COMP) input terminal (or a set of COMP input terminals), (iii) a Universal Serial Bus (USB) input terminal, and/or (iv) a High Definition Multimedia Interface (HDMI) input terminal. Other examples, not shown in FIG. 4A, include composite video.

[0108] In various examples, the input devices of block 445 have associated respective input processing elements as known in the art. For example, the RF portion may be associated with elements suitable for (i) selecting a desired frequency (also referred to as selecting a signal, or band-limiting a signal to a band of frequencies), (ii) downconverting the selected signal, (iii) band-limiting again to a narrower band of frequencies to select (for example) a signal frequency band which may be referred to as a channel in certain examples, (iv) demodulating the downconverted and band-limited signal, (v) performing error correction, and/or (vi) demultiplexing to select the desired stream of data packets. The RF portion of various examples includes one or more elements to perform these functions, for example, frequency selectors, signal selectors, band-limiters, channel selectors, filters, downconverters, demodulators, error correctors, and demultiplexers. The RF portion can include a tuner that performs various of these functions, including, for example, downconverting the received signal to a lower frequency (for example, an intermediate frequency or a near-baseband frequency) or to baseband. In one set-top box example, the RF portion and its associated input processing element receives an RF signal transmitted over a wired (for example, cable) medium, and performs frequency selection by filtering, downconverting, and filtering again to a desired frequency band. Various examples rearrange the order of the above-described (and other) elements, remove some of these elements, and/or add other elements performing similar or different functions. Adding elements can include inserting elements in between existing elements, such as, for example, inserting amplifiers and an analog-to-digital converter. In various examples, the RF portion includes an antenna.

[0109] The USB and/or HDMI terminals can include respective interface processors for connecting system 400 to other electronic devices across USB and/or HDMI connections. It is to be understood that various aspects of input processing, for example, Reed-Solomon error correction, may be implemented, for example, within a separate input processing IC or within processor 410 as necessary. Similarly, aspects of USB or HDMI interface processing may be implemented within separate interface ICs or within processor 410 as necessary. The demodulated, error corrected, and demultiplexed stream is provided to various processing elements, including, for example, processor 410, and encoder/decoder 430 operating in combination with the memory and storage elements to process the datastream as necessary for presentation on an output device.

[0110] Various elements of system 400 may be provided within an integrated housing, Within the integrated housing, the various elements may be interconnected and transmit data therebetween using suitable connection arrangement 425, for example, an internal bus as known in the art, including the Inter-IC (I2C) bus, wiring, and printed circuit boards.

[0111] The system 400 includes communication interface 450 that enables communication with other devices via communication channel 460. The communication interface 450 can include, but is not limited to, a transceiver configured to transmit and to receive data over communication channel 460. The communication interface 450 can include, but is not limited to, a modem or network card and the communication channel 460 may be implemented, for example, within a wired and/or a wireless medium.

[0112] Data is streamed, or otherwise provided, to the system 400, in various examples, using a wireless network such as a Wi-Fi network, for example IEEE 802.11 (IEEE refers to the Institute of Electrical and Electronics Engineers). The Wi-Fi signal of these examples is received over the communications channel 460 and the communications interface 450 which are adapted for Wi-Fi communications. The communications channel 460 of these examples is typically connected to an access point or router that provides access to external networks including the Internet for allowing streaming applications and other over-the-top communications. Other examples provide streamed data to the system 400 using a set-top box that delivers the data over the HDMI connection of the input block 445. Still other examples provide streamed data to the system 400 using the RF connection of the input block 445. As indicated above, various examples provide data in a non-streaming manner. Additionally, various examples use wireless networks other than Wi-Fi, for example, a cellular network or a Bluetooth® network.

[0113] The system 400 can provide an output signal to various output devices, including a display 475, speakers 485, and other peripheral devices 495. The display 475 of various examples includes one or more of, for example, a touchscreen display, an organic light-emitting diode (OLED) display, a curved display, and/or a foldable display. The display 475 may be for a television, a tablet, a laptop, a cell phone (mobile phone), or other device. The display 475 can also be integrated with other components (for example, as in a smart phone), or separate (for example, an external monitor for a laptop). The other peripheral devices 495 include, in various examples, one or more of a stand-alone digital video disc (or digital versatile disc) (DVD, for both terms), a disk player, a stereo system, and/or a lighting system. Various examples use one or more peripheral devices 495 that provide a function based on the output of the system 400. For example, a disk player performs the function of playing the output of the system 400.

[0114] In various examples, control signals are communicated between the system 400 and the display 475, speakers 485, or other peripheral devices 495 using signaling such as AV.Link, Consumer Electronics Control (CEC), or other communications protocols that enable device-to-device control with or without user intervention. The output devices may be communicatively coupled to system 400 via dedicated connections through respective interfaces 470, 480, and 490. Alternatively, the output devices may be connected to system 400 using the communications channel 460 via the communications interface 450. The display 475 and speakers 485 may be integrated in a single unit with the other components of system

400 in an electronic device such as, for example, a television. In various examples, the display interface 470 includes a display driver, such as, for example, a timing controller (T Con) chip.

[0115] The display 475 and speakers 485 can alternatively be separate from one or more of the other components, for example, if the RF portion of input 445 is part of a separate set-top box. In various examples in which the display 475 and speakers 485 are external components, the output signal may be provided via dedicated output connections, including, for example, HDMI ports, USB ports, or COMP outputs.

[0116] The examples may be carried out by computer software implemented by the processor 410 or by hardware, or by a combination of hardware and software. As a non-limiting example, the examples may be implemented by one or more integrated circuits. The memory 420 may be of any type appropriate to the technical environment and may be implemented using any appropriate data storage technology, such as optical memory devices, magnetic memory devices, semiconductor-based memory devices, fixed memory, and removable memory, as non-limiting examples. The processor 410 may be of any type appropriate to the technical environment, and can encompass one or more of microprocessors, general purpose computers, special purpose computers, and processors based on a multi-core architecture, as non-limiting examples.

[0117] Various implementations involve decoding. “Decoding”, as used in this application, can encompass all or part of the processes performed, for example, on a received encoded sequence in order to produce a final output suitable for display. In various examples, such processes include one or more of the processes typically performed by a decoder, for example, entropy decoding, inverse quantization, inverse transformation, and differential decoding. In various examples, such processes also, or alternatively, include processes performed by a decoder of various implementations described in this application, for example, chroma component prediction, etc.

[0118] As further examples, in one example “decoding” refers only to entropy decoding, in another example “decoding” refers only to differential decoding, and in another example “decoding” refers to a combination of entropy decoding and differential decoding. Whether the phrase “decoding process” is intended to refer specifically to a subset of operations or generally to the broader decoding process will be clear based on the context of the specific descriptions and is believed to be well understood by those skilled in the art.

[0119] Various implementations involve encoding. In an analogous way to the above discussion about “decoding”, “encoding” as used in this application can encompass all or part of the processes performed, for example, on an input video sequence in order to produce an encoded bitstream. In various examples, such processes include one or more of the processes typically performed by an encoder, for example, partitioning, differential encoding, transformation, quantization, and entropy encoding. In various examples, such processes also, or alternatively, include processes performed by an encoder of various implementations described in this application, for example, indicating one or more properties to be used for chroma component prediction, etc.

[0120] As further examples, in one example “encoding” refers only to entropy encoding, in another example “encoding” refers only to differential encoding, and in another example “encoding” refers to a combination of differential encoding and entropy encoding. Whether the phrase “encoding process” is intended to refer specifically to a subset of operations or generally to the broader encoding process will be clear based on the context of the specific descriptions and is believed to be well understood by those skilled in the art.

[0121] Note that syntax elements as used herein, for example, coding syntax on transform coefficients, motion vectors, picture partitioning information, etc., are descriptive terms. As such, they do not preclude the use of other syntax element names.

[0122] When a figure is presented as a flow diagram, it should be understood that it also provides a block diagram of a corresponding apparatus. Similarly, when a figure is presented as a block diagram, it should be understood that it also provides a flow diagram of a corresponding method/process.

[0123] The implementations and aspects described herein may be implemented in, for example, a method or a process, an apparatus, a software program, a data stream, or a signal. Even if only discussed in the context of a single form of implementation (for example, discussed only as a method), the implementation of features discussed can also be implemented in other forms (for example, an apparatus or program). An apparatus may be implemented in, for example, appropriate hardware, software, and firmware. The methods may be implemented in, for example, a processor, which refers to processing devices in general, including, for example, a computer, a microprocessor, an integrated circuit, or a programmable logic device. Processors also include communication devices, such as, for example, computers, cell phones, portable/personal digital assistants ("PDAs"), and other devices that facilitate communication of information between end-users.

[0124] Reference to “one example” or “an example” or “one implementation” or “an implementation”, as well as other variations thereof, means that a particular feature, structure, characteristic, and so forth described in connection with the example is included in at least one example. Thus, the appearances of the phrase “in one example” or “in an example” or “in one implementation” or “in an implementation”, as well any other variations, appearing in various places throughout this application are not necessarily all referring to the same example.

[0125] Additionally, this application may refer to “determining” various pieces of information. Determining the information can include one or more of, for example, estimating the information, calculating the information, predicting the information, or retrieving the information from memory. Obtaining may include receiving, retrieving, constructing, generating, and/or determining.

[0126] Further, this application may refer to “accessing” various pieces of information. Accessing the information can include one or more of, for example, receiving the information, retrieving the information (for example, from memory), storing the information, moving the information, copying the information, calculating the information, determining the information, predicting the information, or estimating the information.

[0127] Additionally, this application may refer to “receiving” various pieces of information. Receiving is, as with “accessing”, intended to be a broad term. Receiving the information can include one or more of, for example, accessing the information, or retrieving the information (for example, from memory). Further, “receiving” is typically involved, in one way or another, during operations such as, for example, storing the information, processing the information, transmitting the information, moving the information, copying the information, erasing the information, calculating the information, determining the information, predicting the information, or estimating the information.

[0128] It is to be appreciated that the use of any of the following “/”, “and/or”, and “at least one of”, for example, in the cases of “A/B”, “A and/or B” and “at least one of A and B”, is intended to encompass the selection of the first listed option (A) only, or the selection of the second listed option (B) only, or the selection of both options (A and B). As a further example, in the cases of “A, B, and/or C” and “at least one of A, B, and C”, such phrasing is intended to encompass the selection of the first listed option (A) only, or the selection of the second listed option (B) only, or the selection of the third listed option (C) only, or the selection of the first and the second listed options (A and B) only, or the selection of the first and third listed options (A and C) only, or the selection of the second and third listed options (B and C) only, or the selection of all three options (A and B and C). This may be extended, as is clear to one of ordinary skill in this and related arts, for as many items as are listed.

[0129] Also, as used herein, the word “signal” refers to, among other things, indicating something to a corresponding decoder. Encoder signals may include, for example, a prediction of a chroma component, an indication of a chroma sample (e.g., first and/or second chroma sample), an indication of a reconstructed luma and a chroma, , etc. In this way, in an example the same parameter is used at both the encoder side and the decoder side. Thus, for example, an encoder can transmit (explicit signaling) a particular parameter to the decoder so that the decoder can use the same particular parameter. Conversely, if the decoder already has the particular parameter as well as others, then signaling may be used without transmitting (implicit signaling) to simply allow the decoder to know and select the particular parameter. By avoiding transmission of any actual functions, a bit savings is realized in various examples. It is to be appreciated that signaling may be accomplished in a variety of ways. For example, one or more syntax elements, flags, and so forth are used to signal information to a corresponding decoder in various examples. While the preceding relates to the verb form of the word “signal”, the word “signal” can also be used herein as a noun.

[0130] As will be evident to one of ordinary skill in the art, implementations may produce a variety of signals formatted to carry information that may be, for example, stored or transmitted. The information can include, for example, instructions for performing a method, or data produced by one of the described implementations. For example, a signal may be formatted to carry the bitstream of a described example. Such a signal may be formatted, for example, as an electromagnetic wave (for example, using a radio frequency portion of spectrum) or as a baseband signal. The formatting may include, for example, encoding a data stream and modulating a carrier with the encoded data stream. The information that the signal carries may be, for example, analog or digital information. The signal may be transmitted over a variety of different wired or wireless links, as is known. The signal may be stored on, or accessed or received from, a processor-readable medium.

[0131] Many examples are described herein. Features of examples may be provided alone or in any combination, across various claim categories and types. Further, examples may include one or more of the features, devices, or aspects described herein, alone or in any combination, across various claim categories and types. For example, features described herein may be implemented in a bitstream or signal that includes information generated as described herein. The information may allow a decoder to decode a bitstream, the encoder, bitstream, and/or decoder according to any of the embodiments described. For example, features described herein may be implemented by creating and/or transmitting and/or receiving and/or decoding a bitstream or signal. For example, features described herein may be implemented a method, process, apparatus, medium storing instructions, medium storing data, or signal. For example, features described herein may be implemented by a TV, set-top box, cell phone, tablet, or other electronic device that performs decoding. The TV, set-top box, cell phone, tablet, or other electronic device may display (e.g. using a monitor, screen, or other type of display) a resulting image (e.g., an image from residual reconstruction of the video bitstream). The TV, set-top box, cell phone, tablet, or other electronic device may receive a signal including an encoded image and perform decoding.

[0132] Embodiments described herein may provide additional parameters for the cross-component prediction in video. Embodiments described herein may provide cross-component prediction in video coding. For example, samples of a second chroma component may be predicted from the luma samples (Y) and samples of a first chroma component. In an example, Cb may refer to the first chroma component, and Cr may refer to the second chroma component. In an example, Cr may refer to the first chroma component and Cb may refer to the second chroma component. Examples described herein may extend a linear function for the cross-component intra prediction tools, which may use two linear parameters (e.g., only two linear parameters), into using three linear parameters. The first parameter may be for adjusting the Y samples, the second parameter may be for adjusting the Cb samples, and the third parameter may be for the bias of the linear function. Examples described herein may extend the types of Cb samples that may be used to predict Cr samples: (i) the predicted Cb samples and (ii) the reconstructed Cb samples. The selection on the type of Cb samples that may predict Cr samples and may provide better coding gain with a linear function so as to avoid imposing a delay on predicting the Cb components for one or more configurations and/or applications.

[0133] Cross-component linear model (CCLM) for intra prediction may be provided. The chroma samples may be predicted based on the reconstructed luma samples of the same CU by using a linear model, as follows:

$$pred_C\ (i,j) = \alpha \cdot rec_L(i,j) + \beta \qquad \text{(eq. 1)}$$

where $pred_C\ (i,j)$ may represent the predicted chroma samples in a CU and $rec_L\ (i,j)$ may represent the down-sampled reconstructed luma samples of the same CU.

[0134] The two CCLM parameters (α and β) may be derived with neighboring chroma samples (from above rows and left columns) and their corresponding down-sampled luma samples (LM mode). In an example, four neighboring chroma samples (e.g., at most four neighboring chroma samples) may be used. In an example, the neighboring chroma samples may be selected from above rows (e.g., only) (LM-A mode) or left columns (e.g., only) (LM-L mode) and the selected mode may be signaled.

[0135] The selected neighbouring luma samples at the selected positions are down-sampled and compared to find two smaller values: x^0_A and x^1_A, and two larger values: x^0_B and x^1_B. Their corresponding chroma sample values may be denoted as y^0_A, y^1_A, y^0_B and y^1_B. Then x_A, x_B, y_A and y_B may be derived as:

$$X_a = (x_A^0 + x_A^1 + 1) >> 1$$

$$X_b = (x_B^0 + x_B^1 + 1) >> 1$$

$$Y_a = (y_A^0 + y_A^1 + 1) >> 1$$

$$Y_b = (y_B^0 + y_B^1 + 1) >> 1$$

[0136] The linear model parameters α and β may be obtained according to the following equations:

$$\mathrm{A} = \frac{Y_a - Y_b}{\mathrm{X}_a - X_b}$$

$$\beta = Y_b - \alpha \cdot X_b$$

[0137] FIG. 5 illustrates example locations of one or more samples used for the derivation of α and β. For example, FIG. 5 illustrates an example of a location of the left and above samples and the sample of the current block involved in the CCLM mode.

[0138] In an example, three multi-model LM (MMLM) modes may be added. In an (e.g., each) MMLM mode, the reconstructed neighboring samples may be classified into two classes using a threshold, which may be the average of the reconstructed neighboring luma samples. The linear model of a class (e.g., each class) may be derived using the Least-Mean-Square (LMS) method. For the CCLM mode, the LMS method may be also used to derive the linear model.

[0139] In an example, a slope adjustment may be applied to CCLM and to MMLM prediction. The adjustment may be tilting the linear function, which may map luma values to chroma values with respect to a center point determined by the average luma value of the reference samples, as depicted in FIG. 6.

[0140] FIG. 6 illustrates an example of an effect of the slope adjustment parameter “u.” On the left of FIG. 6, a model may be created with the regular CCLM. On the right of FIG. 6, a model may be updated with slope adjustment.

[0141] Convolutional cross-component model (CCCM) for intra prediction may be provided. The convolutional cross-component model (CCCM) may predict chroma samples from reconstructed luma samples in a similar manner as done by CCLM. The reconstructed luma samples may be down-sampled to match the lower resolution chroma grid when chroma sub-sampling may be used. In an example, there may be an option of using a single model or multi-model example of CCCM. Multi-model CCCM mode may be selected for PUs that may have at least 128 reference samples available. The multi-model example may use two models, one model may be applied to samples that have a value higher than the average luma reference value, and another model may be applied to the rest of the samples (following the spirit of the CCLM design).

[0142] CCCM uses a convolutional filter made of 7 parameters weighting 7 inputs samples $\{si\}i = 0,..6$. Five coefficients may be applied to luminance pixel values corresponding to a plus sign shape, one coefficient to a nonlinear term and the last coefficient to a bias term.

[0143] FIG. 7 illustrates an example spatial part of a convolution filter. The input to the spatial 5-tap component of the filter may include a center (C) luma sample, which may be collocated with the chroma sample to be predicted, and its above/north (N), below/south (S), left/west (W), and right/east (E) neighbors, as shown at 700 in FIG. 7.

[0144] The nonlinear term P may be represented as a power of two of the center luma sample C and scaled to the sample value range of the content:

$$P = (C * C + midVal) >> bitDepth$$

where $midVal$ may be a rounding term. For example, for 10-bit content, it may be calculated as:

$$P = (C * C + 512) >> 10$$

[0145] The bias term B may represent a scalar offset between the input and output (e.g., which may be similar to the offset term in CCLM) and may be set to the middle chroma value (512 for 10-bit content).

[0146] The output of the filter may be calculated as a convolution between the filter coefficients c_i and the input values and then clipped to the range of valid chroma samples:

$$predChromaVal = c0C + c1N + c2S + c3E + c4W + c5P + c6B$$

[0147] FIG. 8 illustrates an example reference area (e.g., with its paddings) that may be used to derive the filter coefficients. The filter coefficients c_i are calculated by minimizing a difference measure (e.g., mean squared error (MSE)) between predicted and reconstructed chroma samples in the reference area (800). FIG. 8 illustrates the reference area, which may include 6 lines/columns of chroma samples above and left of the PU. The reference area may extend one PU width to the right and one PU height below the PU boundaries. The area may be adjusted to include one or more (e.g., only) available samples. The extensions to the area may be seen in FIG. 8 as the shaded samples, for example, at 802. The extensions to the area may be used to support the side samples of the plus-shaped spatial filter and may be padded when in unavailable areas.

[0148] The MSE minimization may be performed by calculating the autocorrelation matrix for the luma input and a cross-correlation vector between the luma input and chroma output.

$$\text{denote } s = \begin{pmatrix} C \\ N \\ S \\ E \\ W \\ P \\ B \end{pmatrix} \text{ where } s_i = \begin{cases} i = 0: C \\ i = 1: N \\ i = 2: S \\ i = 3: E \\ i = 4: W \\ i = 5: P \\ i = 6: B \end{cases}$$

[0149] To derive the coefficients $\{c_i\}$, the autocorrelation matrix may be inverted. For example, the autocorrelation matrix may be LDL^T decomposed, and the filter coefficients (e.g., final filter coefficients) may be calculated using back-substitution. The process follows may roughly the calculation of the ALF filter coefficients. However, LDL^T decomposition (e.g., alternative Cholesky decomposition) may be chosen instead of Cholesky decomposition to avoid using square root operations. In an example, Gaussian elimination technique may be used to invert the matrix. The calculation may use integer 64-bits arithmetic.

[0150] FIG. 9 illustrates an example spatial part of a GL-CCCM convolutional filter. Gradient and location based convolutional cross-component model (GL-CCCM) may be provided. In an example that may include CCCM, the convolution may apply on gradient and location information (e.g., instead of the four spatial neighbor samples) in the CCCM filter. The GL-CCCM filter for the prediction may be:

$$predChromaVal = c0C + c1Gy + c2Gx + c3Y + c4X + c5P + c6B$$

where Gy and Gx may be the vertical and horizontal gradients, respectively, and may be calculated as (see 900, FIG. 9):

$$Gy = (2N + NW + NE) - (2S + SW + SE)$$

$$Gx = (2W + NW + SW) - (2E + NE + SE)$$

[0151] The Y and X parameters may be the vertical and horizontal coordinates of the center luma sample location. The rest of the parameters may be the same as the CCCM tool. The reference area for the parameter calculation may be the same as the CCCM method.

[0152] FIG. 10 illustrates an example spatial part of a non-down-sampled CCCM luma terms, which may be used for a convolutional filter. In an example, the reconstructed luma samples may not be down-sampled to match the lower resolution chroma grid and the co-located reconstructed six luma samples may be used (e.g., may be used directly) as shown in FIG. 10 at 1000. In this example, four non-linear terms may be used and may be built from L_0, L_1, L_2 and L_4 plus the bias B. The number of parameters may be 10.

[0153] Non-local cross-component prediction (NA-CCP) may be provided. FIG. 11 illustrates an example of possible positions of candidate regions. In an example to CCLM and CCCM, samples in regions non-adjacent to the current block may be used to derive a CCCM model for the current block. A candidate region list with 6 candidates may be constructed by checking potential 8×8 regions (e.g., checking potential 8×8 regions in order). If a checked region may be available, it may be put into the candidate region list. The top-left positions of the potential 8×8 regions may be predetermined as shown in FIG. 11. A flag may be signaled to indicate whether NA-CCP may be applied to a chroma block. If NA-CCP may be applied, an index may be signaled to indicate which candidate in the candidate region list may be used to derive the CCCM model.

[0154] In an example to CCLM and CCCM named history-based cross-component prediction (H-CCP) and (H-CCCM) modes, a H-CCLM table and a H-CCCM table may be maintained similar to the HMVP table. After decoding a CCLM or CCCM coded block, the corresponding table may be updated. In an example of implementation of H-CCP, the size of either H-CCLM table or H-CCCM table may be 6. If the current block may be coded with CCLM or CCCM mode, a flag may be signaled to indicate whether H-CCP may be applied. If H-CCP may be used, an index may be further signaled to indicate which candidate model in the H-CCLM table or H-CCCM table may be selected.

[0155] In the cross-component model, chroma samples of both chroma components may be predicted from one or more reconstructed luma samples (e.g., only the reconstructed luma samples) using a 7-tap filter. Two linear parameters may be invoked by a linear function for the cross-component prediction, which may limit the maximum gain of this prediction model.

[0156] FIG. 12 illustrates an example method 1200 for cross-component prediction. Cross-component intra prediction tools (e.g. CCLM, MMLM or CCCM) may be used for chroma prediction using cross-component luma model as in FIG. 12.

[0157] At 1210, the reference samples (reconstructed luma and chroma sample values) are selected from the neighborhood of the current CU. The luma sample values may be filtered to obtain down-sampled luma samples. At 1220, in the case of multi-model, a threshold may be determined to classify the reference samples in at least two classes. At 1230, the parameters of (multi-) model(s) may be derived from the reference luma and chroma sample values. At 1240, the CC-model(s) or cross-component model(s) may allow deriving the chroma sample prediction values from the co-located (down-sampled) reconstructed luma sample values, for example, as computed in (eq. 1). Two linear parameters (e.g., only two linear parameters) may be involved in the cross-component prediction (e.g., α and β). Both chroma components (Cr and Cb) may be predicted based on one or more luma samples (e.g., only from the luma samples).

[0158] The following examples may apply to cross-components intra prediction tools in general (e.g. CCLM, MMLM, or CCCM).

[0159] FIG. 13 illustrates an example method 1300 for using a cross-component prediction when predicting Cb and Cr samples. At 1310, the reference samples are selected. Reference samples may be selected from the neighborhood of the current CU. Reference samples may include reconstructed luma and/or chroma sample values. At 1320, a threshold may be determined to classify the reference samples (e.g., in at least two classes). In an example, there may be variations of a linear model for the second chroma prediction. In an example, a prediction model (e.g., a linear model) for predicting samples of a second chroma component may be based on the reconstructed luma samples and chroma samples of a first chroma component. For example, the prediction of samples of a first chroma component and samples of a second chroma component may be used to predict (e.g., more accurately predict samples) samples of the second chroma component. At 1330, a linear model parameter derivation process for a first chroma prediction may be performed. For example, a modification may be linearly formed so that samples of a first chroma component may be predicted based on the reconstructed luma samples with the two linear parameters function as in (eq. 1), and the samples of a second chroma samples may be predicted by luma samples and the samples of the first chroma component after its prediction process may be done. At 1340, the cross-component prediction may finish the prediction of luma samples, followed by the samples of a first chroma component, and then the samples of a second chroma component. For clarity, (eq. 1) may be rewritten as

$$pred_{Cb}\ (i,j) = \alpha \cdot rec_L(i,j) + \ \beta \qquad \text{(eq. 2)}$$

And, the samples of the second chroma component may be obtained as in

$$pred_{Cr}(i,j) = \alpha \cdot rec_L(i,j) + \beta \cdot rec_{Cb}(i,j) + c \qquad \text{(eq. 3)}$$

where $rec_{Cb}(i,j)$ may be the reconstructed Cb samples(1350). α, β, and c may be the linear parameters to predict the samples of the second chroma component (1360). The process in an example may be depicted as in FIG. 9.

[0160] At 1370, Cr samples are predicted with CC-models. In some examples, Cb samples may be predicted (e.g., first and only) from luma samples, and Cr samples may be predicted (e.g., second), from luma samples and Cb samples. In some examples, Cr samples may be predicted (e.g., first and only) from luma samples, and Cb samples may be predicted (e.g., second), from luma samples and Cr samples. In an example, an encoder may signal to a decoder which chroma component may be predicted first.

[0161] In an example, predicting samples of the second chroma component may be performed by using the predicted samples of the first chroma component, $pred_{Cb}(i,j)$, to avoid delay in the prediction process. This may be useful for some examples or configurations, such as in a low delay application. As described herein, in an example, to get reconstructed samples of a first chroma component, one or more coding processes may be performed before performing the cross-component prediction for samples of a second chroma component. In an example, the predicted samples of a first chroma component may be considered for one or more cases. In an example, using the predicted samples of the first chroma component may (or may not) be as accurate as when using the reconstructed samples. In an example, (eq. 3) may be further modified as:

$$pred_{Cr}(i,j) = \alpha \cdot rec_L(i,j) + \beta \cdot pred_{Cb}(i,j) + c \qquad \text{(eq. 4)}$$

[0162] In one or more examples, the encoder may be able to switch on or off to indicate whether samples of the second chroma component may be predicted using a pair of the reconstructed luma samples and reconstructed samples of a first chroma component or a pair of the reconstructed luma samples and the predicted samples of a first chroma component. This indication may be signaled to the decoder so that the decoder side may properly use the correct prediction properties that are used in the encoder.

[0163] In an example, signaling of the second chroma prediction phase indication and its dependency on the cross-component intra prediction may be provided.

[0164] This example may (e.g., only) work with the cross-component intra prediction enabled. A flag to indicate the second chroma prediction phase may be signaled in the SPS. If the flag is equal to 1, then the second chroma prediction phase may be enabled with the applicable modifications in this example. If the flag is equal to 0, then the second chroma prediction phase may be disabled.

[0165] In an example, other cross component models, such as CCM and GLM, may be provided.

[0166] In an example, CCCM may be used. The examples described herein may be extended from CCLM to other cross-component models. For example, CCCM or GLM may be enhanced by taking into account a first chroma information for a second one. Taking the example of CCCM, the chroma prediction may be done as:

$$predChromaVal = c0C + c1N + c2S + c3E + c4W + c5P + c6B$$

where five luma samples (C, N, S, E and W) may be considered, and seven filter parameters (e.g., including non-linear term and DC value) may be used. *P* may be a non-linear term that may be computed as

$$P = (C*C + 512) >> 10.$$

[0167] In an example, prediction of samples of the second chroma component (e.g., Cr) may employ one or more reconstructed samples of a first chroma component (Cb). For example, the equation may be rewritten as:

$$\begin{aligned} Pred_{cr} &= c0C + c1N + c2S + c3E + c4W + c5P + c6B \\ &+ c0_{cb}C_{cb} + c1_{cb}N_{cb} + c2_{cb}S_{cb} + c3_{cb}E_{cb} + c4_{cb}W_{cb} + c5_{cb}P_{cb} \end{aligned}$$

where five chroma samples (e.g., $C_{cb}, N_{cb}, S_{cb}, E_{cb}, E_{cb}, W_{cb}$) may be considered and seven filter parameters (e.g., including non-linear term and DC value) may be used. P_{cb} may be a non-linear term that may be computed as:

$$P_{cb} = (C_{cb} * C_{cb} + 512) >> 10.$$

[0168] The decoding process may include one or more actions. A CCCM model between a luma component and a first chroma component Cb may be learned. A model to predict and reconstruct the first chroma component Cb may be applied. A CCCM model may be learned between the luma component, the first chroma component Cb, and a second chroma component (Cr). The model may be applied using luma and Cb to predict and reconstruct Cr.

An example may be simplified by considering one or more of the following: the non-linear term of Cb may be removed, the central value of Cr may be used (e.g., using only the central value of Cr may be used), the predicted sample values may be used instead of the reconstructed sample values of Cb.

[0169] A GLM may be enhanced in a similar manner as described herein regarding CCCM. For example, Cb reconstructed/predicted samples may be used along with luma samples to predict Cr samples. For example, a GLM model may be defined as:

$$predChromaVal = c0C + c1Gy + c2Gx + c3Y + c4X + c5P + c6B$$

[0170] The formula above may be modified for Cr in this example as:

$$Pred_{cr} = c0C + c1Gy + c2Gx + c3Y + c4X + c5P + c6B$$
$$+ c0_{cr}C_{cr} + c1_{cr}Gy_{cr} + c2_{cr}Gx_{cr} + c3_{cr}C_{cr} + c4X_{cr} + c5_{cr}P_{cr}$$

[0171] Similar simplification may be considered as for CCCM, which may include one or more of the following: the non-linear term of Cb may be removed, the central value of Cr may be used (e.g., only the central value of Cr may be used), the predicted sample values instead reconstructed sample values of Cb may be used.

[0172] Systems, methods, and instrumentalities are disclosed for video encoding. A reconstructed luma value and a chroma sample value may be determined. The reconstructed luma value and the chroma sample value may be associated with a current coding unit (CU). A first parameter and a second parameter associated with a linear model may be determined using the chroma sample value. A first predicted chroma sample value may be determined using the first parameter, the second parameter, and the reconstructed luma value. A reconstructed chroma sample value may be determined using the first predicted chroma sample value and the linear model. A second predicted chroma sample value may be determined using the first reconstructed chroma sample value. The current coding block may be encoded based on the second predicted chroma sample value.

[0173] In an example, on a condition that a multi-model is used, a threshold may be determined to classify at least the reconstructed luma value or the chroma sample value. In an example, a third parameter associated with the linear model may be determined. In an example, the linear model may be determined. In an example, the second predicted chroma sample value may be determined using the first parameter, the reconstructed chroma sample value, the reconstructed luma sample, and the third parameter.

[0174] Systems, methods, and instrumentalities are disclosed for video decoding. A reconstructed luma value and a chroma sample value may be determined. The reconstructed luma value and the chroma sample value may be associated with a current coding unit (CU). A first parameter and a second parameter associated with a linear model may be determined using the chroma sample value. A first predicted chroma sample value may be determined using the first parameter, the second parameter, and the reconstructed luma value. A reconstructed chroma sample value may be determined using the first predicted chroma sample value and the linear model. A second predicted chroma sample value may be determined using the first reconstructed chroma sample value. The current coding block may be decoded based on the second predicted chroma sample value.

[0175] In an example, on a condition that a multi-model is used, a threshold may be determined to classify at least the reconstructed luma value or the chroma sample value. In an example, a third parameter associated with the linear model may be determined. In an example, the linear model may be determined. In an example, the second predicted chroma sample value may be determined using the first parameter, the reconstructed chroma sample value, the reconstructed luma sample, and the third parameter.

[0176] Although features and elements are described above in particular combinations, one of ordinary skill in the art will appreciate that each feature or element can be used alone or in any combination with the other features and elements. In addition, the methods described herein may be implemented in a computer program, software, or firmware incorporated in a computer-readable medium for execution by a computer or processor. Examples of computer-readable media include electronic signals (transmitted over wired or wireless connections) and computer-readable storage media. Examples of computer-readable storage media include, but are not limited to, a read only memory (ROM), a random access memory (RAM), a register, cache memory, semiconductor memory devices, magnetic media such as internal hard disks and removable disks, magneto-optical media, and optical media such as CD-ROM disks, and digital versatile disks (DVDs). A processor in association with software may be used to implement a radio frequency transceiver for use in a WTRU, UE, terminal, base station, RNC, or any host computer.

CLAIMS

1. A video encoding device comprising a processor configured to:

determine a second predicted chroma component sample value, wherein the second predicted chroma component sample value is determined based on a reconstructed first chroma component sample value and a first plurality of linear model parameters;

predict a second chroma component sample using the second predicted chroma component sample value to obtain a second predicted chroma component sample; and

encode a coding block using at least the second predicted chroma component sample.

2. The video encoding device of claim 1, wherein the processor is further configured to:

determine the second predicted chroma component sample value based on a reconstructed luma sample value.

3. The video encoding device of any one of claims 1-2, wherein the processor is further configured to:

determine a first predicted chroma component sample value, wherein the first predicted chroma component sample value is determined based on a reconstructed luma sample value and a second plurality of linear model parameters;

predict a first chroma component sample using the first predicted chroma component sample value to obtain a first predicted chroma component sample; and

reconstruct the first chroma component sample using the first predicted chroma component sample to generate the reconstructed first chroma component sample value.

4. The video encoding device of claim 3, wherein the second plurality of linear model parameters comprises a first parameter associated with a luma sample, and a second parameter associated with a chroma sample value.

5. The video encoding device of any one of claims 1-4, wherein the first plurality of linear model parameters comprises a first parameter associated with a luma sample value, a second parameter associated with a chroma sample value, and a third parameter associated with biasing a linear model.

6. The video encoding device of any one of claims 1-5, wherein the processor is further configured to:

indicate, in video data, whether the second predicted chroma component sample value is determined based on the reconstructed first chroma component sample value or the first predicted chroma component sample value.

7. The video encoding device of any one of claims 3-6, wherein the first plurality of linear model parameters and the second plurality of linear model parameters are derived from a cross-component linear model (CCLM), a multi-model linear model (MMLM), or a convolutional cross-component model (CCCM).

8. The video encoding device of any one of claims 2-3, wherein the first plurality of linear model parameters or the second plurality of linear model parameters are derived from a multi-model linear model (MMLM), and wherein the processor is further configured to:

determine a threshold to classify at least the reconstructed luma value.

9. A video decoding device comprising a processor configured to:

determine a second predicted chroma component sample value, wherein the second predicted chroma component sample value is determined based on a reconstructed first chroma component sample value and a first plurality of linear model parameters;

predict a second chroma component sample using the second predicted chroma component sample value to obtain a second predicted chroma component sample; and

decode a coding block using at least the second predicted chroma component sample.

10. The video decoding device of claim 9, wherein the processor is further configured to:

determine the second predicted chroma component sample value based on a reconstructed luma sample value.

11. The video decoding device of any one of claims 9-10, wherein the processor is further configured to:

determine a first predicted chroma component sample value, wherein the first predicted chroma component sample value is determined based on a reconstructed luma sample value and a second plurality of linear model parameters;

predict a first chroma component sample using the first predicted chroma component sample value to obtain a first predicted chroma component sample; and

reconstruct the first chroma component sample using the first predicted chroma component sample to generate the reconstructed first chroma component sample value.

12. The video decoding device of claim 11, wherein the second plurality of linear model parameters comprises a first parameter associated with a luma sample, and a second parameter associated with a

chroma sample value.

13. The video decoding device of any one of claims 9-12, wherein the first plurality of linear model parameters comprises a first parameter associated with a luma sample value, a second parameter associated with a chroma sample value, and a third parameter associated with biasing a linear model.

14. The video decoding device of any one of claims 9-13, wherein the processor is further configured to:

indicate, in video data, whether the second predicted chroma component sample value is determined based on the reconstructed first chroma component sample value or the first predicted chroma component sample value.

15. The video decoding device of any one of claims 11-14, wherein the first plurality of linear model parameters and the second plurality of linear model parameters are derived from a cross-component linear model (CCLM), a multi-model linear model (MMLM), or a convolutional cross-component model (CCCM).

16. The video decoding device of any one of claims 10-11, wherein the first plurality of linear model parameters or the second plurality of linear model parameters are derived from a multi-model linear model (MMLM), and wherein the processor is further configured to:

determine a threshold to classify at least the reconstructed luma value.

17. A method for video encoding comprising:

determining a second predicted chroma component sample value, wherein the second predicted chroma component sample value is determined based on a reconstructed first chroma component sample value and a first plurality of linear model parameters;

predicting a second chroma component sample using the second predicted chroma component sample value to obtain a second predicted chroma component sample; and

encoding a coding block using at least the second predicted chroma component sample.

18. The method of claim 17, further comprising:

determining the second predicted chroma component sample value based on a reconstructed luma sample value.

19. The method of any one of claims 17-18, further comprising:

determining a first predicted chroma component sample value, wherein the first predicted chroma component sample value is determined based on a reconstructed luma sample value and a second plurality of linear model parameters;

predicting a first chroma component sample using the first predicted chroma component sample value to obtain a first predicted chroma component sample; and

reconstructing the first chroma component sample using the first predicted chroma component sample to generate the reconstructed first chroma component sample value.

20. The method of claim 19, wherein the second plurality of linear model parameters comprises a first parameter associated with a luma sample, and a second parameter associated with a chroma sample value.

21. The method of any one of claims 17-20, wherein the first plurality of linear model parameters comprises a first parameter associated with a luma sample value, a second parameter associated with a chroma sample value, and a third parameter associated with biasing a linear model.

22. The method of any one of claims 17-21, further comprising:

indicating, in video data, whether the second predicted chroma component sample value is determined based on the reconstructed first chroma component sample value or the first predicted chroma component sample value.

23. The method of any one of claims 19-22, wherein the first plurality of linear model parameters and the second plurality of linear model parameters are derived from a cross-component linear model (CCLM), a multi-model linear model (MMLM), or a convolutional cross-component model (CCCM).

24. The method of any one of claims 18-19, wherein the first plurality of linear model parameters or the second plurality of linear model parameters are derived from a multi-model linear model (MMLM), and wherein the method further comprises:

determining a threshold to classify at least the reconstructed luma value.

25. A method for video decoding comprising:

determining a second predicted chroma component sample value, wherein the second predicted chroma component sample value is determined based on a reconstructed first chroma component sample value and a first plurality of linear model parameters;

predicting a second chroma component sample using the second predicted chroma component sample value to obtain a second predicted chroma component sample; and

decoding a coding block using at least the second predicted chroma component sample.

26. The method of claim 25, further comprising:

determining the second predicted chroma component sample value based on a reconstructed luma sample value.

27. The method of any one of claims 25-26, further comprising:

determining a first predicted chroma component sample value, wherein the first predicted chroma component sample value is determined based on a reconstructed luma sample value and a second plurality of linear model parameters;

predicting a first chroma component sample using the first predicted chroma component sample value to obtain a first predicted chroma component sample; and

reconstructing the first chroma component sample using the first predicted chroma component sample to generate the reconstructed first chroma component sample value.

28. The method of claim 27, wherein the second plurality of linear model parameters comprises a first parameter associated with a luma sample, and a second parameter associated with a chroma sample value.

29. The method of any one of claims 25-28, wherein the first plurality of linear model parameters comprises a first parameter associated with a luma sample value, a second parameter associated with a chroma sample value, and a third parameter associated with biasing a linear model.

30. The method of any one of claims 25-29, further comprising:

indicating, in video data, whether the second predicted chroma component sample value is determined based on the reconstructed first chroma component sample value or the first predicted chroma component sample value.

31. The method of any one of claims 27-30, wherein the first plurality of linear model parameters and the second plurality of linear model parameters are derived from a cross-component linear model (CCLM), a multi-model linear model (MMLM), or a convolutional cross-component model (CCCM).

32. The method of any one of claims 30-31, wherein the first plurality of linear model parameters or the second plurality of linear model parameters are derived from a multi-model linear model (MMLM), and wherein the method further comprises:

determining a threshold to classify at least the reconstructed luma value.

33. A video encoding device comprising a processor, wherein the processor is configured to implement the

steps of a method according to any one of claims 17-24, or 25-32.

34. A video decoding device comprising a processor, wherein the processor is configured to implement the steps of a method according to any one of claims 17-24, or 25-32.

35. A computer program product which is stored on a non-transitory computer readable medium and comprises program code instructions for implementing the steps of a method according to any one of claims 17-24, or 25-32 when executed by a processor.

36. Video data comprising information representative of the encoded coding block generated according to the method of one of claims 17-24.

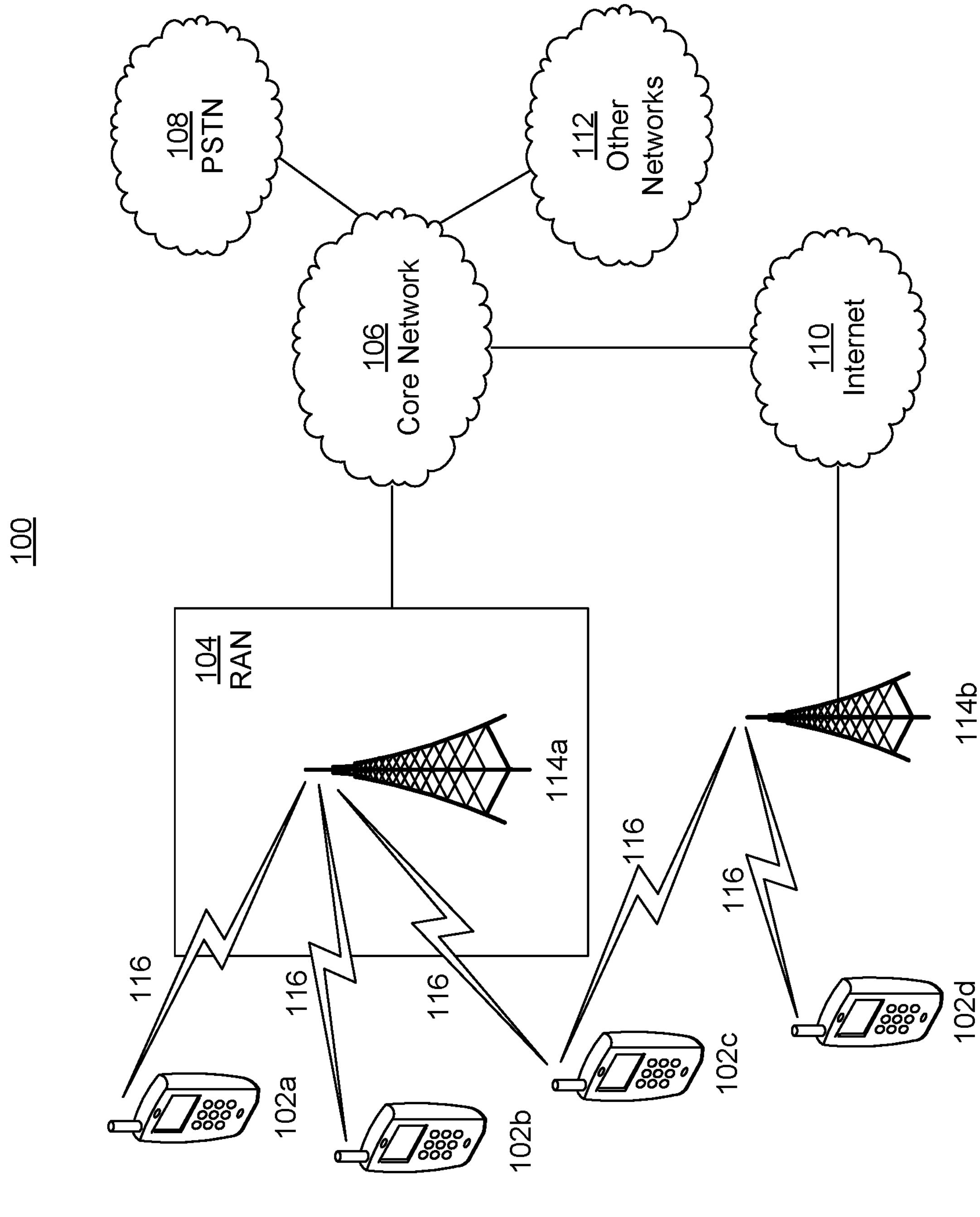

100
104
RAN
106
Core Network
108
PSTN
110
Internet
112
Other
Networks
114a
114b
116
116
116
116
116
102a
102b
102c
102d

FIG. 1A

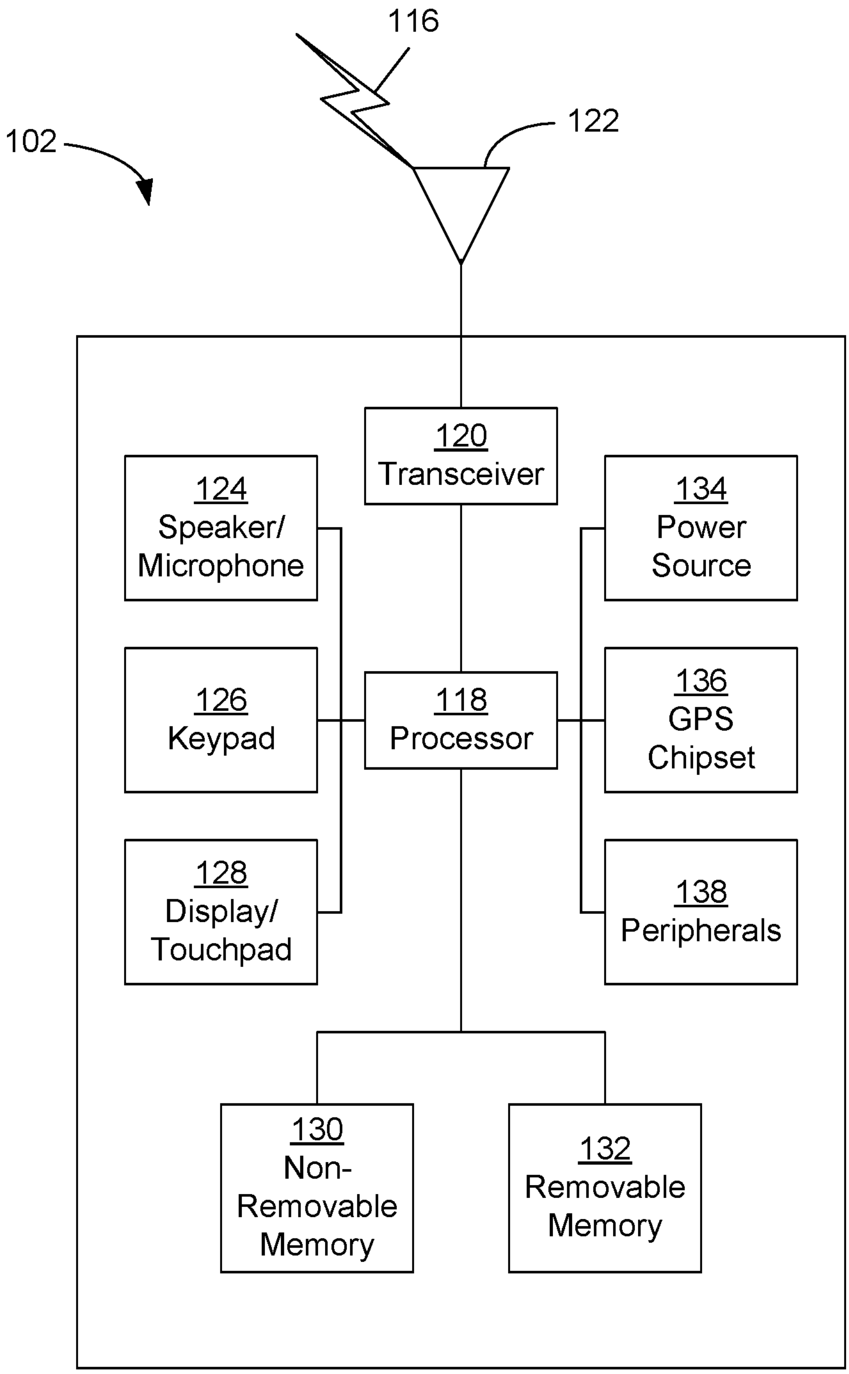

116
122
102
120
Transceiver
124
Speaker/
Microphone
134
Power
Source
126
Keypad
118
Processor
136
GPS
Chipset
128
Display/
Touchpad
138
Peripherals
130
Non-
Removable
Memory
132
Removable
Memory

FIG. 1B

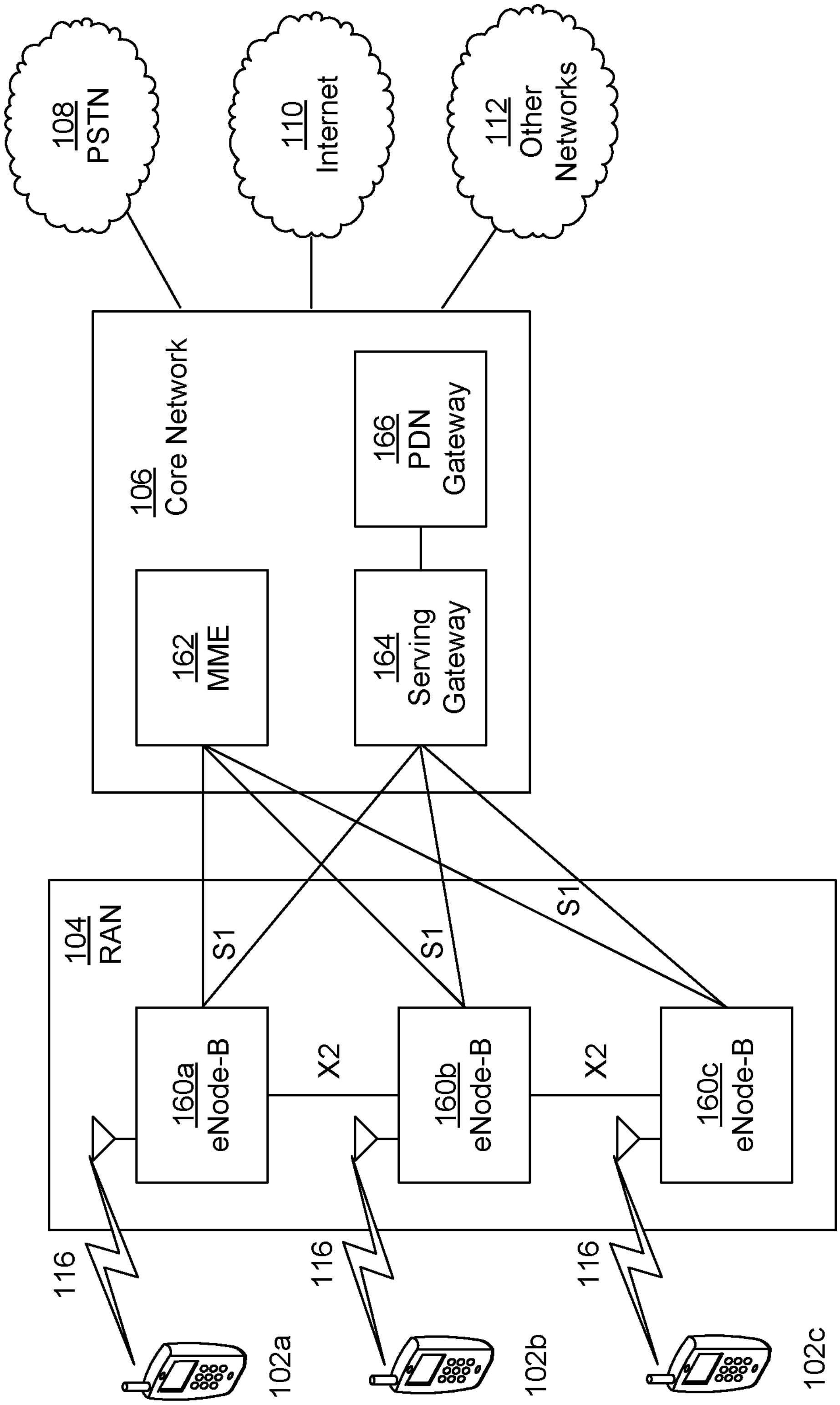

108
PSTN
110
Internet
112
Other
Networks
106
Core Network
162
MME
164
Serving
Gateway
166
PDN
Gateway
104
RAN
S1
S1
S1
160a
eNode-B
X2
160b
eNode-B
X2
160c
eNode-B
116
116
116
102a
102b
102c

FIG. 1C

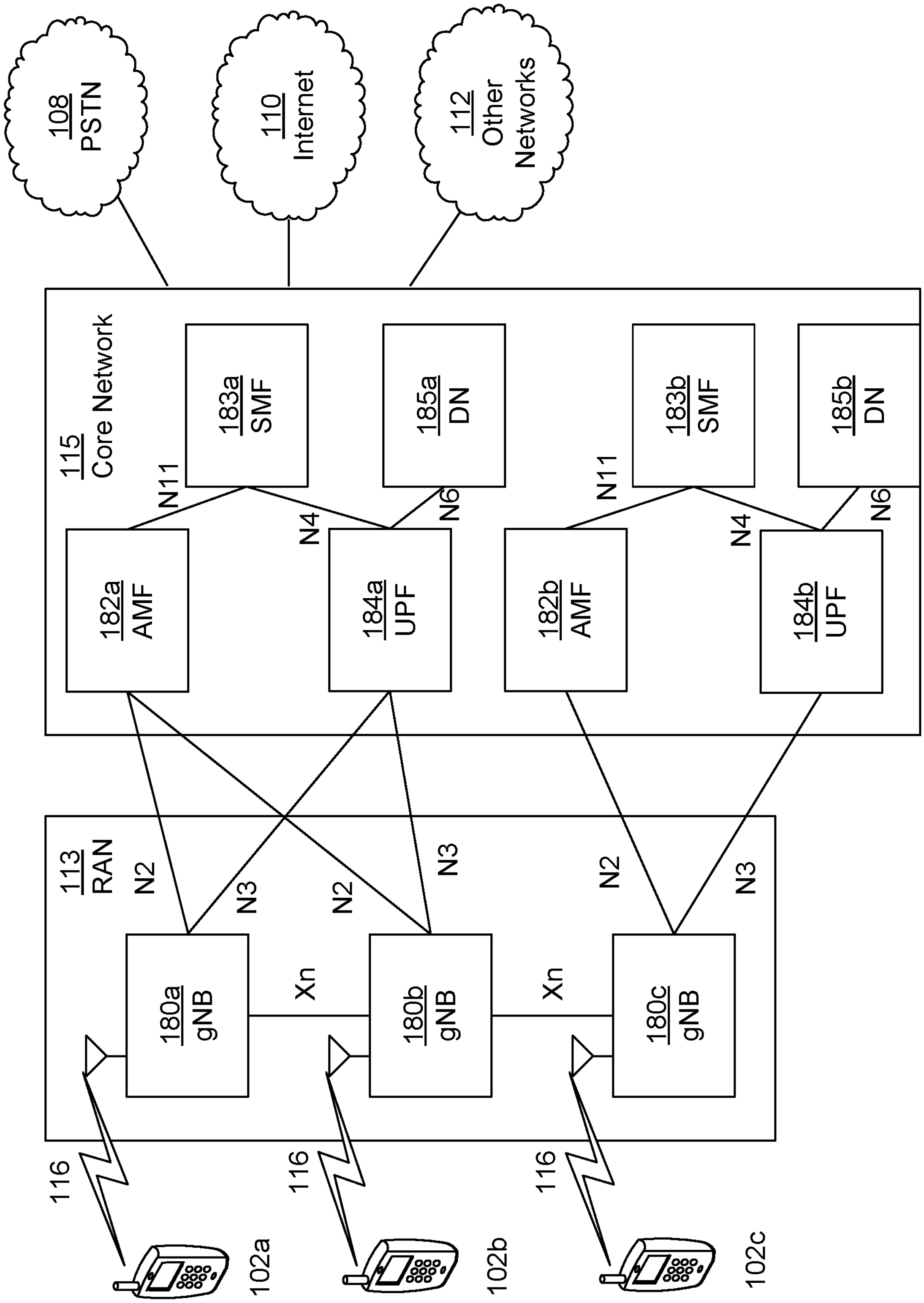

108
PSTN
110
Internet
112
Other
Networks
115
Core Network
183a
SMF
185a
DN
183b
SMF
185b
DN
182a
AMF
184a
UPF
182b
AMF
184b
UPF
N11
N4
N6
N11
N4
N6
113
RAN
N2
N3
N2
N3
N2
N3
180a
gNB
180b
gNB
180c
gNB
Xn
Xn
116
116
116
102a
102b
102c

FIG. 1D

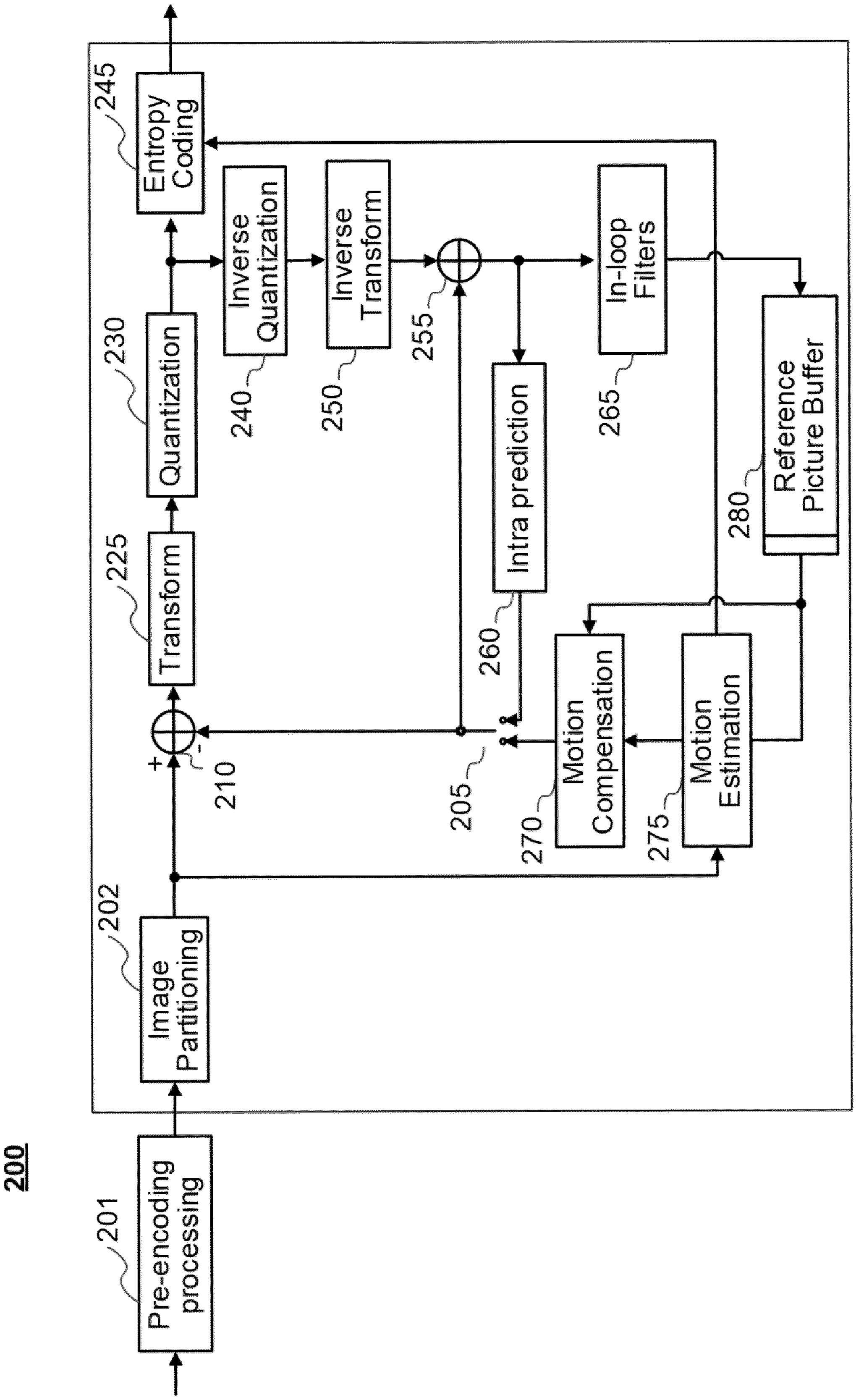

200
201
Pre-encoding processing
202
Image Partitioning
210
+
-
225
Transform
230
Quantization
240
Inverse Quantization
245
Entropy Coding
250
Inverse Transform
255
260
Intra prediction
265
In-loop Filters
205
270
Motion Compensation
275
Motion Estimation
280
Reference Picture Buffer

FIG. 2

300

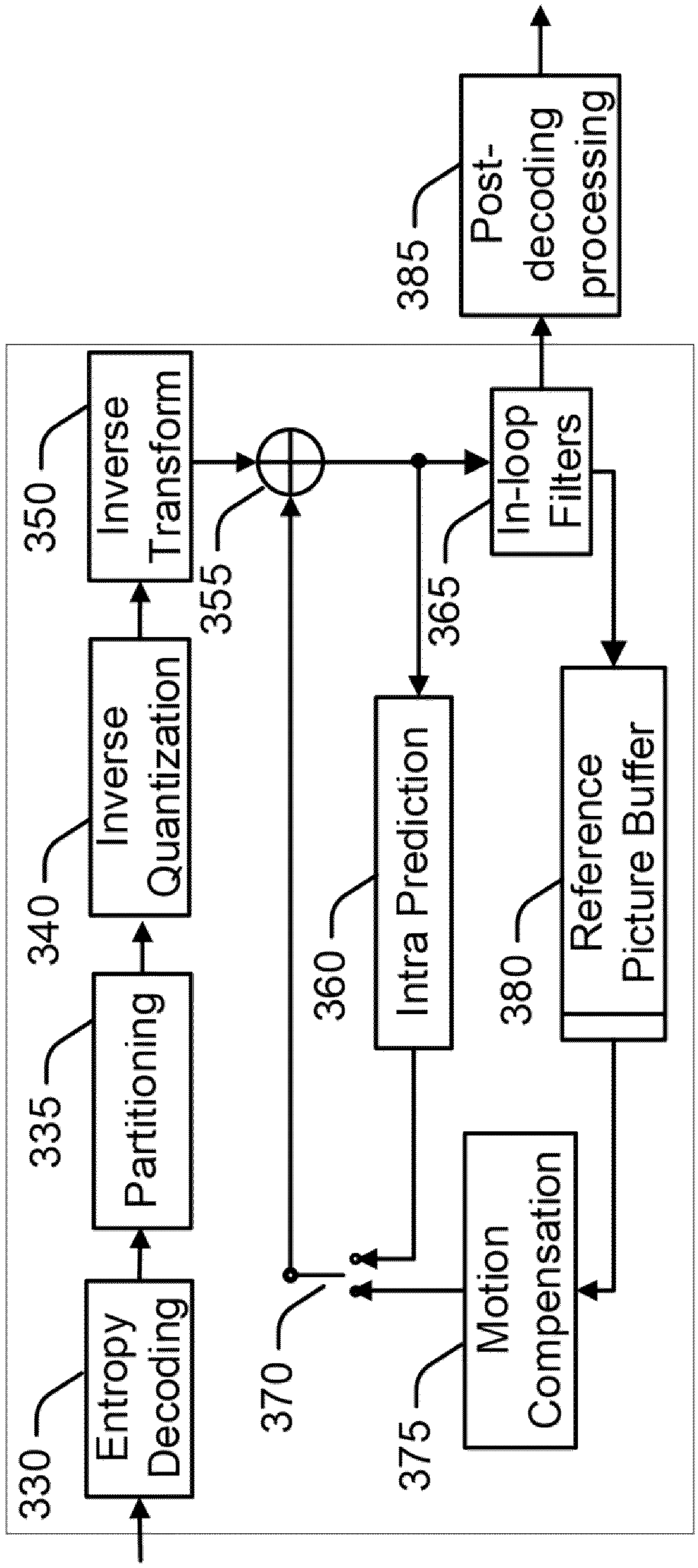

330
Entropy Decoding
335
Partitioning
340
Inverse Quantization
350
Inverse Transform
355
360
Intra Prediction
365
In-loop Filters
370
375
Motion Compensation
380
Reference Picture Buffer
385
Post-decoding processing

FIG. 3

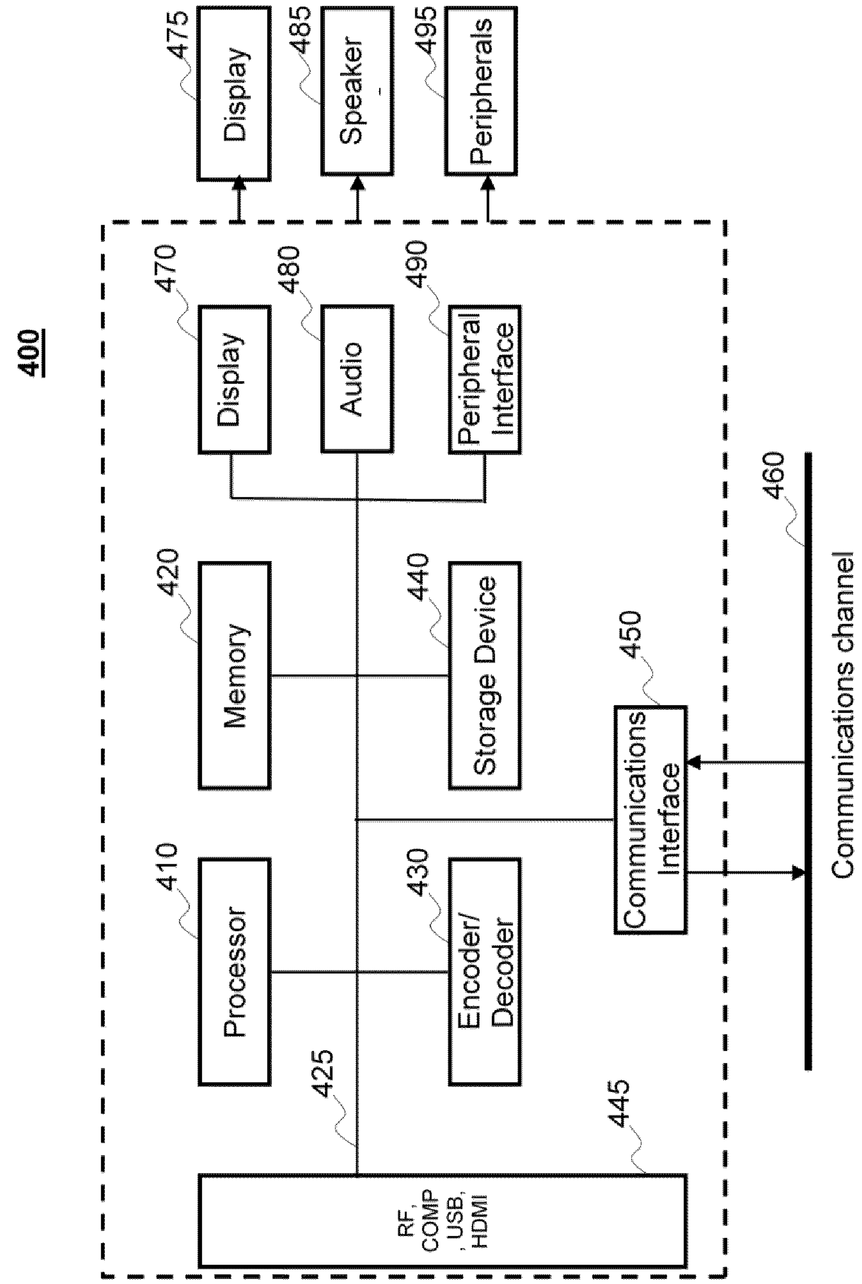

400
475
Display
485
Speaker
495
Peripherals
470
Display
480
Audio
490
Peripheral Interface
420
Memory
440
Storage Device
450
Communications Interface
460
Communications channel
410
Processor
430
Encoder/ Decoder
425
445
RF, COMP , USB, HDMI

FIG. 4

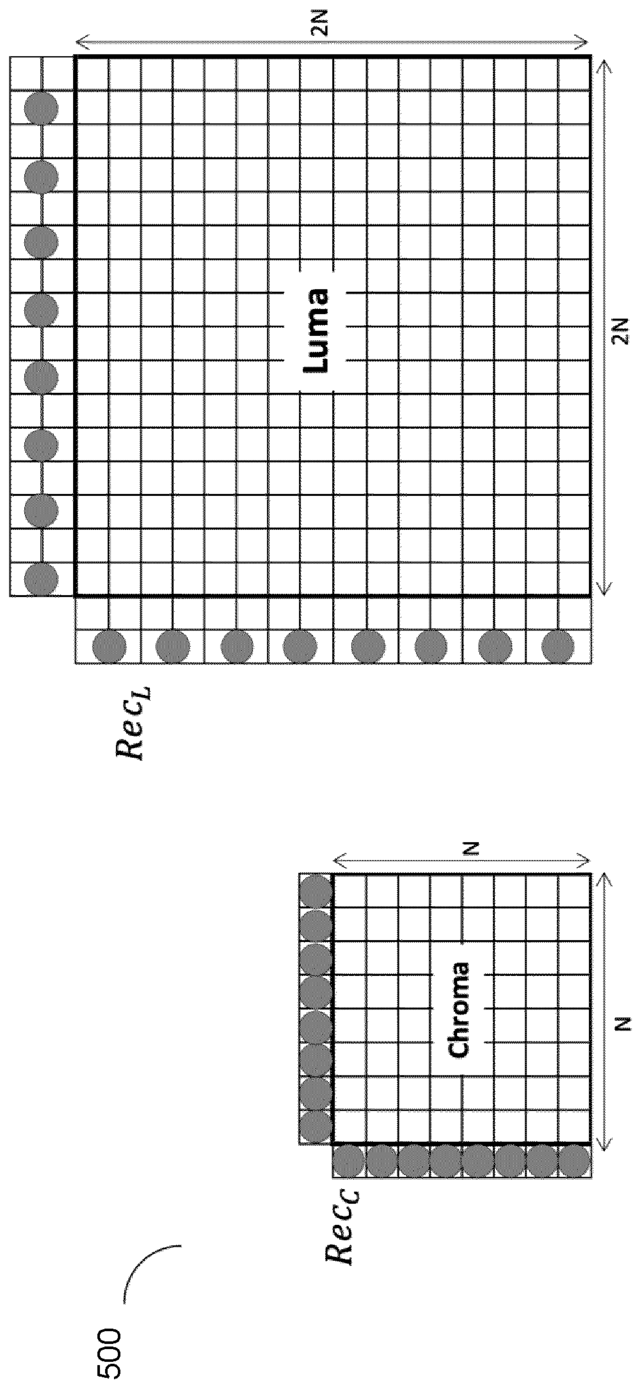


FIG. 5

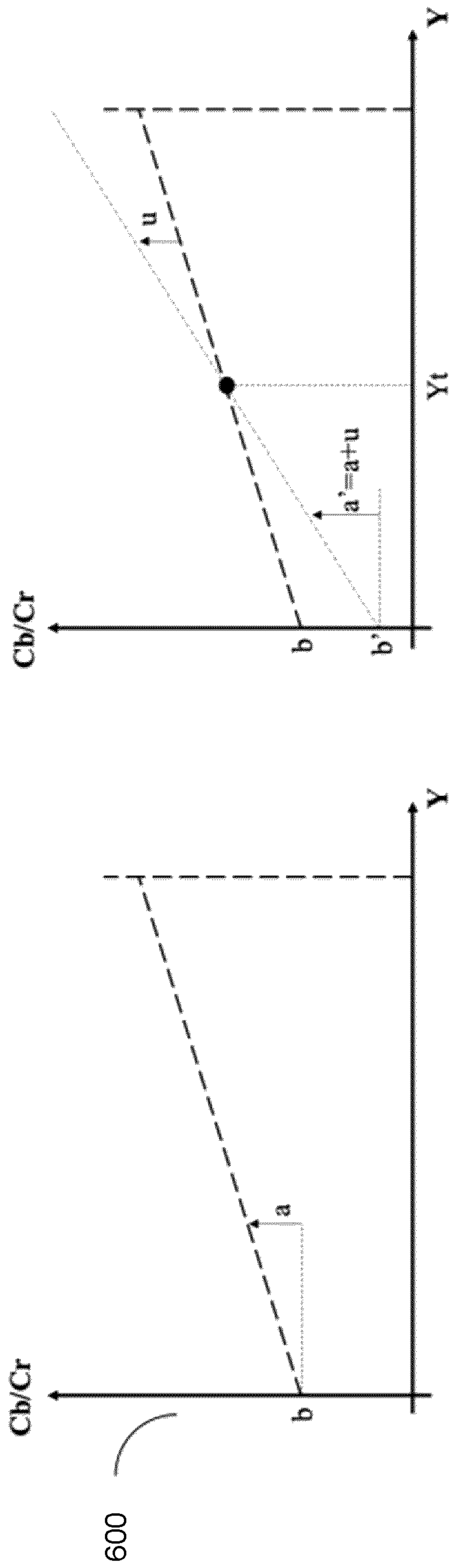


FIG. 6

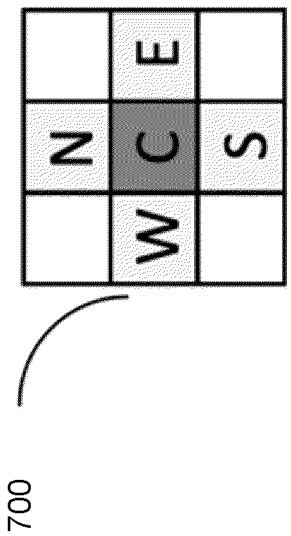


FIG. 7

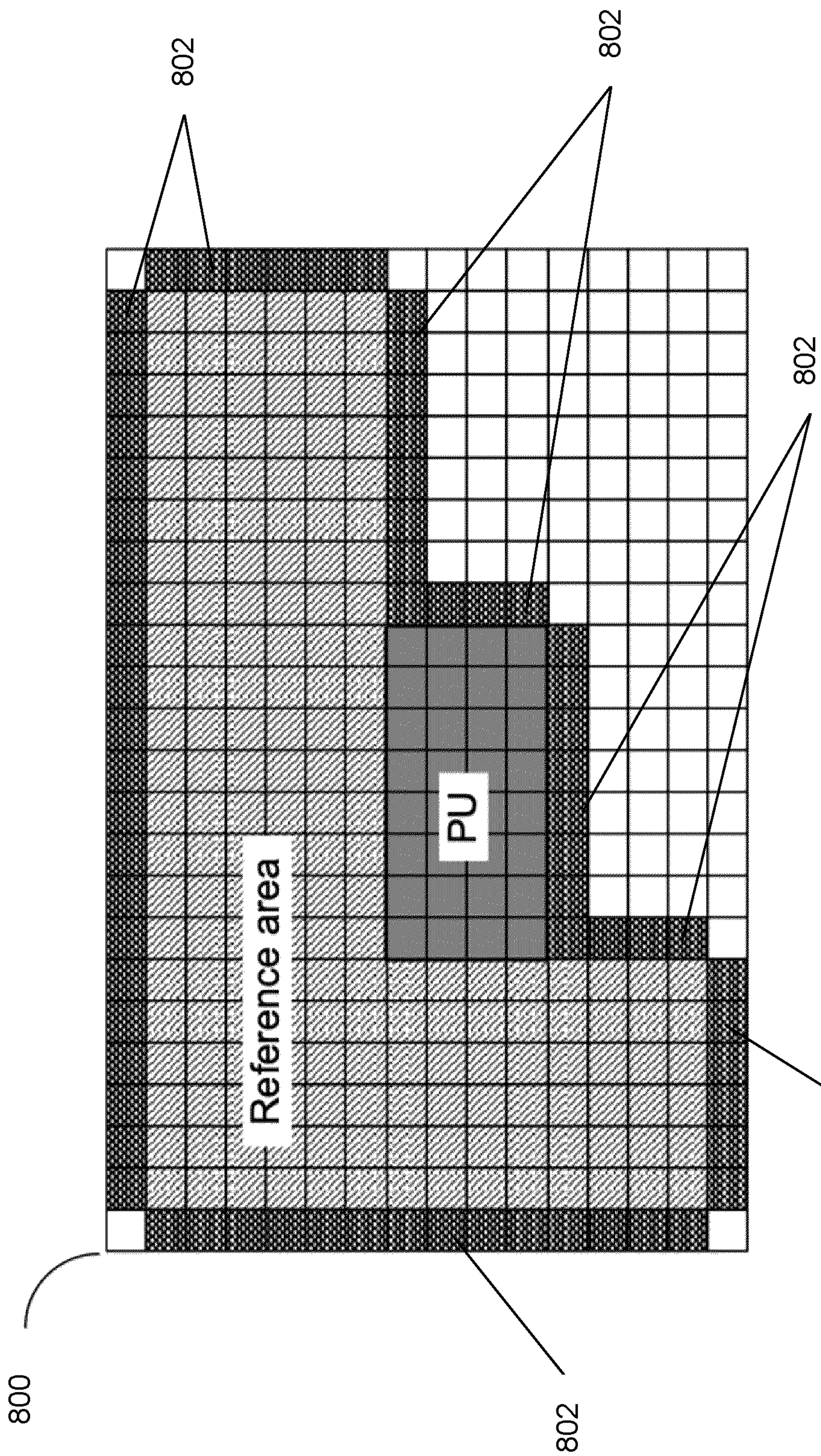
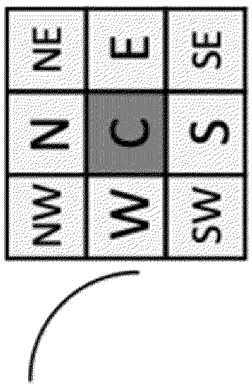


FIG. 8



900

FIG. 9

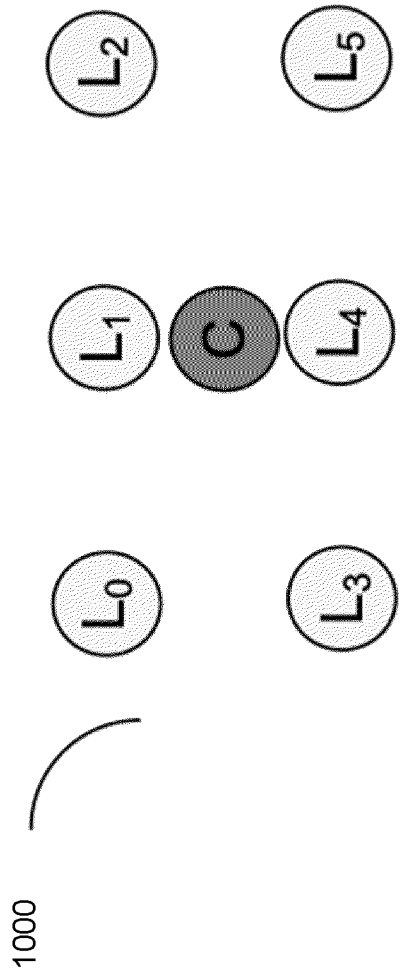


FIG. 10

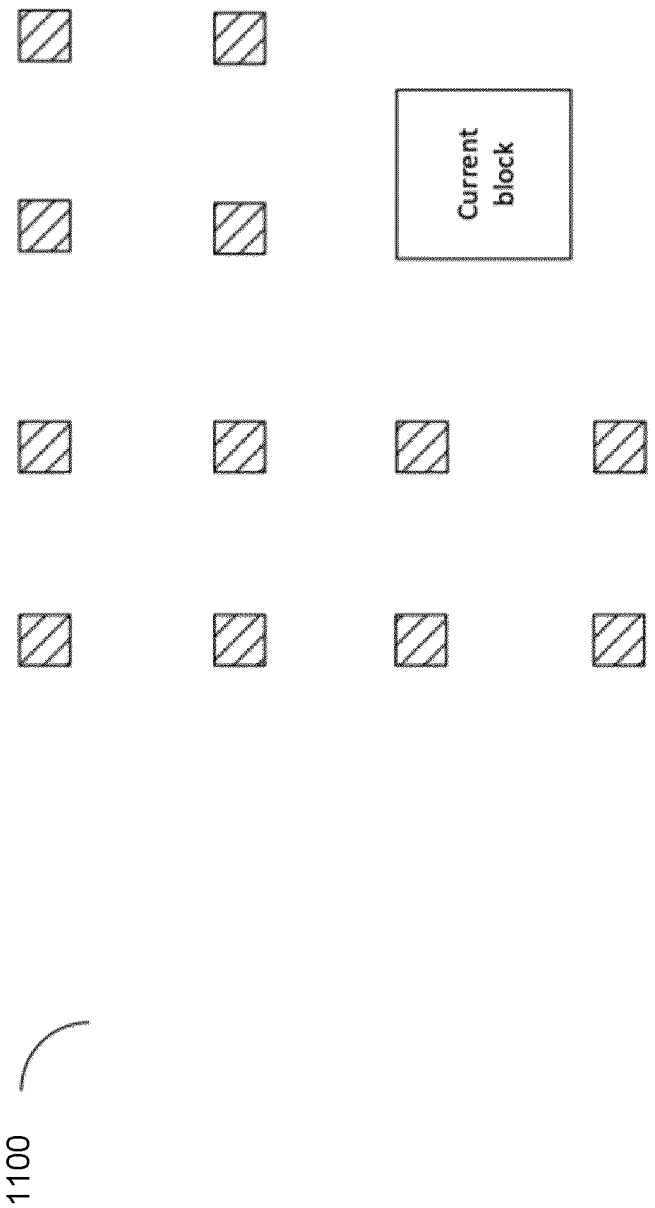


FIG. 11

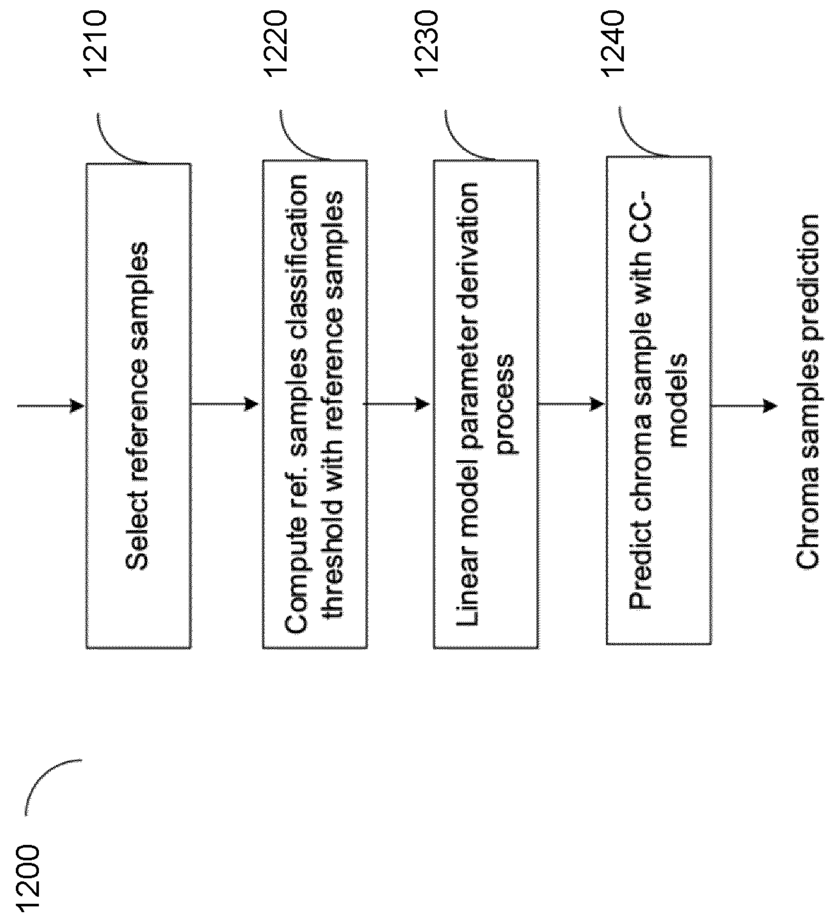

1200
1210
Select reference samples
1220
Compute ref. samples classification threshold with reference samples
1230
Linear model parameter derivation process
1240
Predict chroma sample with CC-models
Chroma samples prediction

FIG. 12

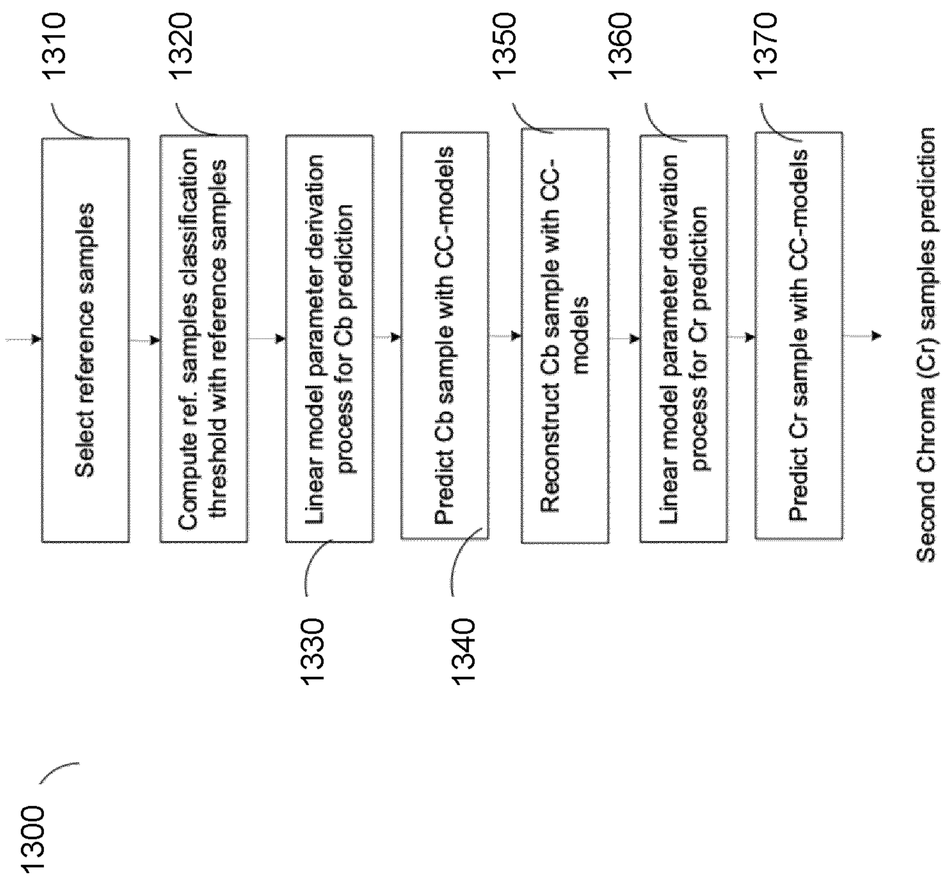

1300
1310
Select reference samples
1320
Compute ref. samples classification threshold with reference samples
1330
Linear model parameter derivation process for Cb prediction
1340
Predict Cb sample with CC-models
1350
Reconstruct Cb sample with CC-models
1360
Linear model parameter derivation process for Cr prediction
1370
Predict Cr sample with CC-models
Second Chroma (Cr) samples prediction

FIG. 13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2024/066193

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims;; it is covered by claims Nos.:
1-5, 7-13, 15-21, 23-29, 31-36

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/066193

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04N19/105 H04N19/186 H04N19/593
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04N

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

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

EPO-Internal, COMPENDEX, INSPEC, IBM-TDB, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	TAO ZHANG ET AL: "Improving chroma intra prediction for HEVC", 2016 IEEE INTERNATIONAL CONFERENCE ON MULTIMEDIA & EXPO WORKSHOPS (ICMEW), IEEE, 11 July 2016 (2016-07-11), pages 1-6, XP032970872, DOI: 10.1109/ICMEW.2016.7574735 the whole document -----	1-5, 7-13, 15-21, 23-29, 31-36

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[x] Further documents are listed in the continuation of Box C.

[x] See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
6 September 2024	07/11/2024

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Ferré, Pierre

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	LI JUNRU ET AL: "Prediction With Multicross Component for Future Video Coding", IEEE MULTIMEDIA, IEEE SERVICE CENTER, NEW YORK, NY, US, vol. 28, no. 3, 27 November 2020 (2020-11-27), pages 52-62, XP011878962, ISSN: 1070-986X, DOI: 10.1109/MMUL.2020.3041008 [retrieved on 2021-09-17] the whole document	1-5, 7-13, 15-21, 23-29, 31-36
X	WO 2017/139937 A1 (MEDIATEK SINGAPORE PTE LTD [SG]; ZHANG KAI [CN] ET AL.) 24 August 2017 (2017-08-24)	1-5, 7-13, 15-21, 23-29, 31-36
	paragraph [0002] - paragraph [0005] paragraph [0012] - paragraph [0014]	
A	COBAN M ET AL: "Algorithm description of Enhanced Compression Model 8 (ECM 8)", 141. MPEG MEETING; 20230116 - 20230120; ONLINE; (MOTION PICTURE EXPERT GROUP OR ISO/IEC JTC1/SC29/WG11), , no. m62440 ; JVET-AC2025 6 April 2023 (2023-04-06), XP030308550, Retrieved from the Internet: URL:https://dms.mpeg.expert/doc_end_user/documents/141_Teleconference/wg11/m62440-JVET-AC2025-v1-JVET-AC2025.zip JVET-AC2025-v1.docx [retrieved on 2023-04-06] * sections 3.1.1, 3.1.13 *	1-5, 7-13, 15-21, 23-26
A	BROWNE A ET AL: "Algorithm description for Versatile Video Coding and Test Model 19 (VTM 19)", 141. MPEG MEETING; 20230116 - 20230120; ONLINE; (MOTION PICTURE EXPERT GROUP OR ISO/IEC JTC1/SC29/WG11), , no. m62432 ; JVET-AC2002 7 April 2023 (2023-04-07), XP030308547, Retrieved from the Internet: URL:https://dms.mpeg.expert/doc_end_user/documents/141_Teleconference/wg11/m62432-JVET-AC2002-v1-JVET-AC2002-v1.zip JVET-AC2002-v1.docx [retrieved on 2023-04-07] * section 3.3.2 *	1-5, 7-13, 15-21, 23-26

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2024/066193

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2017139937 A1	24-08-2017	CN 109417623 A	01-03-2019
		EP 3403407 A1	21-11-2018
		TW 201740734 A	16-11-2017
		US 2019045184 A1	07-02-2019
		WO 2017139937 A1	24-08-2017
		WO 2017140211 A1	24-08-2017

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-5, 7-13, 15-21, 23-29, 31-36

   How to predict the second chroma component

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2. claims: 6, 14, 22, 30

   How to adapt delay and complexity of the prediction process

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