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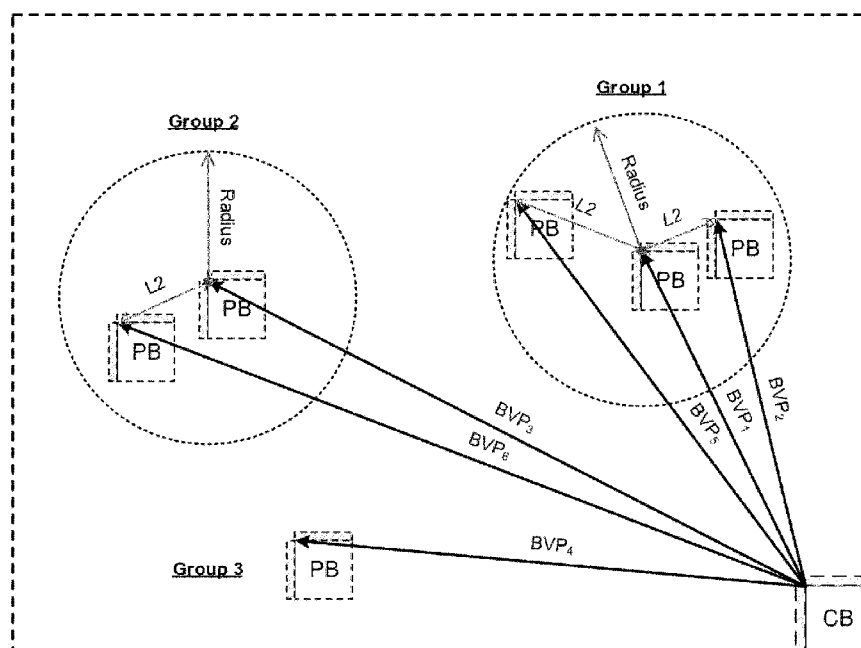


FIG. 7

(57) Abstract: An intra-template (e.g., IntraTMP) fusion mode may be used for video encoding and/or decoding. For a current block, an intra block copy (IBC) merge candidate list may be constructed, and the candidate list may include a candidate corresponding to intra-template fusion. The current block may be encoded and/or decoded based on the intra block copy (IBC) merge candidate list. Based on determining that the candidate corresponding to intra template fusion is used for the current block, the multiple intra-template predictors may be obtained for the current block. For a current block, an intra block copy (IBC) merge candidate list having a candidate corresponding to intra-template fusion mode may be obtained. Predicting the current block may be determined based on the candidate corresponding to intra-template fusion mode. A plurality of block vectors may be derived based on the candidate. The current block may be decoded based on the plurality of block vectors.



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INTRA BLOCK COPY MERGE MODE WITH INTRA TEMPLATE MATCHING**CROSS-REFERENCE TO RELATED APPLICATIONS**

[0001] This application claims the benefit of European Provisional Application No. EP23306110.0, 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 performing intra-template (e.g., IntraTMP) fusion mode for video encoding and/or decoding. For a current block, an intra block copy (IBC) merge candidate list may be constructed, and the candidate list may include a candidate corresponding to intra-template fusion. The current block may be encoded and/or decoded based on the intra block copy (IBC) merge candidate list.

[0004] Based on determining that the candidate corresponding to intra template fusion is used for the current block, the multiple intra-template predictors may be obtained for the current block. The intra-template matched blocks (e.g., intra-template predictors) may be fused together. A prediction block may be generated based on a fusing of the intra-template matched blocks. The current block may be encoded and/or decoded based on the prediction block.

[0005] Based on determining that the candidate corresponding to intra template fusion is used for the current block, the multiple intra-template predictors may be obtained for the current block. Block vectors may be obtained based on the multiple intra-template predictors. A prediction block may be generated based on the block vectors. For example, a bi-predicted prediction block may be generated based on two block vectors obtained via intra template matching prediction. The current block may be encoded and/or decoded based on the prediction block.

[0006] The intra-template fusion may include the determining an intra-template fusion weight type. The intra-template fusion weight type may include a Wiener-filter based weight derivation type.

[0007] Performing intra-template fusion may include deriving multiple intra-template matched blocks. The deriving of the plurality of intra-template matched blocks may include determining a candidate set.

[0008] Performing intra-template fusion may include determining a precision index for a current block. The precision index may indicate a sub-pel precision.

[0009] For a current block, an intra block copy (IBC) merge candidate list having a candidate corresponding to intra-template fusion mode may be obtained. Predicting the current block may be determined based on the candidate corresponding to intra-template fusion mode. A plurality of block vectors may be derived based on the candidate. The current block may be encoded or decoded based on the plurality of block vectors.

[0010] A first prediction block may be obtained based on a first block vector of the derived plurality of block vectors. A second prediction block may be obtained based on a second block vector of the derived plurality of block vectors. A fused prediction block may be determined by fusing the first prediction block and the second prediction block. The current block may be determined to be decoded based on the fused prediction block.

[0011] The first prediction block and the second prediction block may be fused based on a fusion weight type and a fusion index associated with the candidate.

[0012] A set of filtering parameters associated with the candidate may be obtained based on filtering being enabled for the candidate corresponding to intra-template fusion mode. A reference block of the current block may be filtered based on the set of filtering parameters associated with the candidate. The current block may be decoded based on the filtered reference block.

[0013] Sub-pixel information of the candidate corresponding to intra-template fusion mode may be determined. The plurality of block vectors may be derived based on the sub-pixel information.

[0014] Sub-pixel information of the candidate corresponding to intra-template fusion mode may be determined. It may be determined to derive the plurality of block vectors at a quarter pixel precision based on the sub-pixel information of the candidate indicating that subpixel is used in intra-template matching.

[0015] A template mode search type associated with the candidate may be obtained. The plurality of block vectors may be refined based on the template mode search type. The current block may be decoded based on the plurality of refined block vectors.

[0016] 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.

[0017] FIG. 1A is a system diagram illustrating an example communications system in which one or more disclosed embodiments may be implemented.

5 [0018] 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.

[0019] 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.

10 [0020] 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.

[0021] FIG. 2 illustrates an example video encoder.

[0022] FIG. 3 illustrates an example video decoder.

15 [0023] FIG. 4 illustrates an example of a system in which various aspects and examples may be implemented.

[0024] FIG. 5 illustrates an example intra-template matching search area.

[0025] FIG. 6 illustrates example padding candidates for a replacement of a zero-vector in an intra block copy (IBC) list.

20 [0026] FIG. 7 illustrates example IBC candidate clustering (e.g., clustering based on an L2 distance and a template matching (TM) cost).

[0027] FIG. 8 illustrates an example IBC reference region, where the region may depend on a current coding unit (CU) position, for example.

25 [0028] FIG. 9 illustrates an example reference area for IBC with coding tree unit (CTU) (m, n) being coded.

DETAILED DESCRIPTION

[0029] A more detailed understanding may be had from the following description, given by way of example in conjunction with the accompanying drawings.

30 [0030] 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.

[0031] 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.

[0032] 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.

[0033] 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.

[0034] 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).

[0035] 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).

[0036] 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).

[0037] 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).

[0038] 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., a eNB and a gNB).

[0039] 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.

[0040] 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.

[0041] 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.

[0042] 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.

[0043] 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.

[0044] 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.

[0045] 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.

[0046] 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.

[0047] 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.

[0048] 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.

[0049] 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).

[0050] 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.

[0051] 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.

[0052] 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.

[0053] 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)).

[0054] 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.

[0055] 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.

[0056] 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.

[0057] 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.

[0058] 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.

[0059] 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.

[0060] 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.

[0061] 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.

[0062] 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.

[0063] In representative embodiments, the other network 112 may be a WLAN.

[0064] 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.

[0065] 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 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.

[0066] 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.

[0067] 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).

[0068] 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).

[0069] 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.

[0070] 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.

[0071] 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.

[0072] 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, 180b 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).

[0073] 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).

[0074] 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.

[0075] 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.

[0076] 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.

[0077] 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 162 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.

[0078] 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.

[0079] 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 184a, 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.

[0080] 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.

[0081] 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.

[0082] 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 performing testing using over-the-air wireless communications.

[0083] 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 test 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.

[0084] 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.

[0085] The aspects described and contemplated in this application may be implemented in many different forms. FIGS. 5-9 described herein may provide some examples, but other examples are contemplated. The discussion of FIGS. 5-9 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.

[0086] 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.

[0087] 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.

[0088] 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 future-developed, 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.

[0089] Various numeric values are used in examples described the present application, such as number of candidates and/or candidate sets, number of available precision levels and their corresponding precision values, and the like. These and other specific values are for purposes of describing examples and the aspects described are not limited to these specific values.

[0090] 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.

[0091] 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 may be associated with the pre-processing, and attached to the bitstream.

[0092] 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, coding units (CUs). 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.

[0093] The prediction residuals are then transformed (225) and quantized (230). The quantized transform coefficients, as well as motion vectors and other syntax elements, 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.

[0094] 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) filtering to reduce encoding artifacts. The filtered image is stored at a reference picture buffer (280).

[0095] 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.

[0096] In particular, the input of the decoder includes a video bitstream, which may be generated by video encoder 200. The bitstream is first entropy decoded (330) to obtain transform coefficients, 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 may 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).

[0097] 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. In an example, the decoded images (e.g.,

after application of the in-loop filters (365) and/or after post-decoding processing (385), if post-decoding processing is used) may be sent to a display device for rendering to a user.

[0098] 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.

[0099] 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.

[0100] 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.

[0101] 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.

[0102] 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.

[0103] 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.

[0104] 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
5 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.

10 **[0105]** 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
15 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.

20 **[0106]** 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.

[0107] The system 400 includes communication interface 450 that enables communication with
25 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.

30 **[0108]** 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
35 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.

5 **[0109]** 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
10 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
15 example, a disk player performs the function of playing the output of the system 400.

[0110] 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
20 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
25 driver, such as, for example, a timing controller (T Con) chip.

[0111] 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
30 ports, USB ports, or COMP outputs.

[0112] 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
35 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.

[0113] 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, determining to employ intra-template fusion for a current block, deriving a plurality of intra-template matched blocks, and generating a prediction signal based on a fusing of the plurality of intra-template matched blocks.

[0114] 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.

[0115] 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, determining to employ intra-template fusion for a current block, deriving a plurality of intra-template matched blocks, generating a prediction signal based on a fusing of the plurality of intra-template matched blocks; and the like.

[0116] 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.

[0117] Note that syntax elements as used herein, for example, coding syntax on precision factors, shifts, number of fraction bits etc., are descriptive terms. As such, they do not preclude the use of other syntax element names. For example, the syntax elements may include flag indications (such as an indication of whether intra-template fusion mode is used). The syntax

elements may include an index that specifies a candidate set to be used for intra-template fusion. The syntax elements may include an indication of a weight type to be used with intra-template fusion. The syntax elements may include an index that specifies block vector candidates. The syntax elements may include an precision index (for example, a precision index that includes sub-pel precision).

[0118] 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.

[0119] 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.

[0120] 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 as any other variations, appearing in various places throughout this application are not necessarily all referring to the same example.

[0121] 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.

[0122] 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.

[0123] 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.

[0124] 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.

[0125] Also, as used herein, the word “signal” refers to, among other things, indicating something to a corresponding decoder. Encoder signals may include, for example, signaling with regard to whether intra-template fusion is used. The encoder signals may include information relevant to intra-template fusion operation as disclosed herein. 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.

[0126] 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.

[0127] 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.

[0128] Merge mode of IBC may be performed. An IBC merge index may refer to an intra-template matching prediction (IntraTMP) candidate. IntraTMP block vector information may be translated to the IBC domain. Such a translation may result, for example, in improved performance (e.g., improved accuracy of prediction).

[0129] Certain information from IntraTMP that may be used, as discussed herein, when an IBC merge index refers to an IntraTMP coded block. For example, information such as fusion mode of IntraTMP, IntraTMP filtering mode, and/or sub-pixel IntraTMP, may be used for merge IBC mode.

[0130] IntraTMP may include an intra prediction mode that, inter alia, copies a prediction block (e.g., the best prediction block) from a reconstructed part of a current frame, e.g., whose L-shaped template matches a current template. For example, for a predefined search range, the encoder may search for a similar template (e.g., the most similar template) to the current template in a reconstructed part of the current frame. The encoder may use the corresponding block as a prediction block. The encoder may then signal the usage of this mode. In an example, a

corresponding prediction operation (e.g., a same prediction operation) may be performed at the decoder side.

[0131] The prediction signal may be generated by matching the L-shaped causal neighbor of the current block with another block in a predefined search area, for example as shown in FIG.

5 5. To illustrate, in FIG. 5, R1 may represent a current CTU, R2 may represent a top-left CTU, R3 may represent an above CTU, and R4 may represent a left CTU. Here, a sum of absolute differences (SAD) may be used as a cost function, for example. Other cost functions may be used for template matching search.

10 **[0132]** Within each region, the decoder may search for a template that has an appropriate SAD (e.g., a least SAD) with respect to the current one. The decoder may use its corresponding block as a prediction block.

[0133] The dimensions of all regions (SearchRange_w, SearchRange_h) may be set proportional to the block dimension (BlkW, BlkH), e.g., to have a fixed number of SAD comparisons per pixel. That is, in an example:

$$\begin{aligned} \text{SearchRange_w} &= a * \text{BlkW} \\ \text{SearchRange_h} &= a * \text{BlkH} \end{aligned}$$

Where 'a' may represent a constant that controls the gain/complexity trade-off. In an example, 'a' may be equal to 5.

20 **[0134]** FIG. 5 may illustrate an intra template matching search area to be used. The search range of search regions (e.g., all search regions) may be subsampled by a factor of 2 (e.g., to speed-up the template matching process). This may lead to a reduction of template matching search by 4. After finding a match (e.g., the best match), a refinement process may be performed. The refinement may be done via a second template matching search around the match (e.g., best match) with a reduced range. The reduced range may be defined as $\min(\text{BlkW}, \text{BlkH})/2$.

25 **[0135]** In an example, the Intra template matching tool may be enabled for CUs with size less than or equal to 64 in width and height. This maximum CU size for intra template matching may be configurable.

30 **[0136]** The intra template matching prediction mode may be signaled (e.g., at a CU level) through an indication (e.g., a dedicated flag). For example, intra template matching prediction mode may be signaled (e.g., at a CU level) through a dedicated flag when DIMD is not used for current CU.

35 **[0137]** Multi-candidate IntraTMP may be considered. A candidate list may be constructed with candidate block vectors (BV) ranked in ascending order of their template matching costs. An index of the selected candidate may be signalled in the video data (e.g., bitstream) to indicate the prediction block.

[0138] IntraTMP fusion may be performed. Multiple IntraTMP matched blocks may be derived. IntraTMP fusion may include fusing the multiple IntraTMP matched blocks (e.g., to produce a better overall prediction).

[0139] Sub-pel precision may be considered in IntraTMP. The sub-pel positions around the integer-pel position obtained by template matching may be further enabled to IntraTMP. For example, a DCT-IF filter may be used for sub-pel interpolation.

[0140] IntraTMP with a filter model may be considered. For example, parameters may use a template of the current block and a corresponding matching template. The prediction block may be obtained by applying the model to filter the reference block.

[0141] An IntraTMP fusion method may cause the blending of multiple reference blocks. The blending of multiple reference blocks may be used to derive a final prediction block. In an example, the final prediction block may be derived via a Wiener-filter based weight derivation method. Reference blocks may be obtained by block vectors (BVs) in template matching search process, for example.

[0142] Certain IntraTMP modes may be considered, such as “left template”, “above template”, and “L-shape fusion” modes. For example, the left and above template modes may employ a left side or an above side to derive template matching candidates. For example, a fusion mode may fuse two or more L-shape candidates (e.g., the best 2, the best 5, or the like, L-shape candidates). For example, the fusion mode may fuse two or more L-shape candidates via a specified technique, such as a template matching cost-based technique and/or a MSE minimization based linear combination formula, or the like.

[0143] The search range of IntraTMP may include a search range that is extended to the adjacent search area of IntraTMP. The search range of the IntraTMP may include a search range that is extended to enlarge the search range for small blocks.

[0144] An example syntax for IntraTMP, as disclosed herein, may be represented as follows:

...
intra_tmp_flag
if(intra_tmp_flag) {
intra_tmp_fusion_flag
if(intra_tmp_fusion_flag) {
intra_tmp_fusion_weight_type
intra_tmp_fusion_idx
} else{

intra_tmp_idx
intra_tmp_filter_flag
if(!intra_tmp_filter_flag) {
intra_tmp_sub_pel_precision_idx
if(intra_tmp_sub_pel_precision_idx != 0) {
intra_tmp_sub_pel_direction_idx
}
}
}
}
...

[0145] The intra_tmp_flag may indicate whether the intra prediction type for current block is IntraTMP or not. The intra_tmp_fusion_flag may indicate whether fusion is used or not for current block. The intra_tmp_fusion_idx may specify the candidate set used for IntraTMP fusion. The range of intra_tmp_fusion_idx may include 0 to 2, for example. The intra_tmp_fusion_idx may be used to indicate a candidate set. For example, the index may indicate one of the three candidate sets (e.g., {BV0 to BV4}, {BV5 to BV9}, {BV10 to BV14}.) The intra_tmp_fusion_weight_type may indicate whether the SAD based weight derivation method or the Wiener-filter based weight derivation method is used. The intra_tmp_idx may specify the index of BV in the candidate list used for current block. The range of intra_tmp_idx may be 0 to 18, for example. Candidates from L-shape template, top template and left template may be included in the same candidate list. The intra_tmp_sub_pel_precision_idx may specify a precision index for current block. The range of intra_tmp_sub_pel_precision_idx may include 0 to 3, for example, indicating integer-pel precision, 1/2-pel precision, 1/4-pel precision and 3/4-pel precision, respectively. The intra_tmp_sub_pel_direction_idx may specify the sub-pel direction index for current block. The range of intra_tmp_sub_pel_phase_idx may include 0 to 7.

[0146] An IBC merge/AMVP list may be constructed. For example, if (e.g., only if) an IBC merge/AMVP candidate is valid, the candidate may be inserted into the IBC merge/AMVP candidate list. Above-right, bottom-left, and above-left spatial candidates and a pairwise average candidate may be added into the IBC merge/AMVP candidate list. Template based adaptive reordering (ARMC-TM) may be applied to IBC merge list.

[0147] The HMVP table size for IBC may be 25. After up to 20 IBC merge candidates are derived (e.g., with full pruning), the candidates may be reordered together. After reordering, one or more candidates with low template matching costs (e.g., the first 6 candidates with the lowest template matching costs) may be selected as the candidates in an IBC merge list.

[0148] The zero vectors' candidates to pad the IBC Merge/AMVP list may be replaced with a set of BVP candidates located in the IBC reference region. A zero vector may be invalid as a block vector in IBC merge mode. An invalid vector may be discarded as BVP in the IBC candidate list.

5 [0149] FIG. 6 illustrates example padding candidates for a replacement of a zero-vector in an intra block copy (IBC) list. Candidates (e.g., three candidates) may be located on the nearest corners of the reference region. Additional candidates (e.g., three additional candidates) may be determined in the middle of the three sub-regions (A, B, and C), whose coordinates may be determined by the width, and height of the current block and the ΔX and ΔY parameters, as is depicted in FIG. 6, for example.

[0150] FIG. 7 illustrates example IBC candidate clustering (e.g., clustering based on an L2 distance and a template matching (TM) cost). During the IBC AMVP list construction, a clustering of the BVP candidates may be applied when both BV candidate components are non-zero. The clustering with L2 distance may be applied (e.g., applied if there are more than 2 valid BV candidates and up to 6 candidates are clustered). The clustering radius may be defined as:

$$Radius = \log_2((cbWidth \cdot cbHeight) \gg MIN_PU_SIZE)$$

[0151] The clustering method may be applied in the candidate list order. The candidates assigned to a group may be removed from the list for the subsequent clusters. In a (e.g., each) group, a BVP (e.g., the BVP with a lowest TM cost) may be selected as the representative candidate of that group. Representative candidates (e.g., representative candidates of the two first groups) may be chosen as the candidates for the IBC AMVP list.

[0152] A directional indication may be signalled. For example, if a candidate component is zero or a block is coded in Reconstruction-Reordered IBC (RRIBC), a flag may be signalled to indicate this case with a directional flag indicating horizontal or vertical component is non-zero. New BVP candidates (e.g., two new BVP candidates) may be derived. The sign of the non-zero BV component may be derived at decoder side, for example. In an example, the AMVP BVP0 may be set to a location (e.g., the nearest valid location) to the current block, e.g., $(-cbWidth$ or $-cbHeight)$. In this example, the non-zero BVD may be negative (e.g., always negative), pointing to the left for a BV with a zero vertical component or to the above for a BV with a zero horizontal component. Likewise, the AMVP BVP1 may be set to a position (e.g., the farthest position) from the current block in the valid reference region. For example, it may be set to a position that is the left boundary or the top boundary of the IBC search region. In an example, if the BVP1 is selected, the BVD may be positive (e.g., always positive), pointing to the right for BV with a zero vertical component or to the bottom for BV with a zero horizontal component.

[0153] The optimal IBC AMVP index may be signalled. The index may allow deriving the sign of the non-zero BVD component at the decoder side. The absolute magnitude of non-zero BVD

component may be signalled. In RRIBC, the direction of the flipping mode may be derived from the signalled directional flag.

[0154] Template matching may be used in IBC. For example, template matching may be used for IBC merge mode. For example, template matching may be used for IBC AMVP mode. For example, template matching may be used for both IBC merge mode and IBC AMVP mode.

[0155] The IBC-TM merge list may be modified relative to a non-template-matching IBC merge mode. For example, the IBC-TM merge list may be presented such that candidates are selected according to a pruning method with a motion distance between the candidates (e.g., as in TM merge mode). For example, the ending zero motion fulfillment may be replaced by motion vectors to the left $(-W, 0)$, top $(0, -H)$ and top-left $(-W, -H)$, where W is the width and H the height of the current CU.

[0156] In the IBC-TM merge mode, the selected candidates may be refined with a template matching. For example, the selected candidates may be refined with a template matching method prior to the RDO and/or decoding process. In an example, the IBC-TM merge mode may be put in competition with a non-template-matching IBC merge mode. An indication, such as a TM-merge flag, may be signaled to indicate whether TM-merge is enabled/used (e.g., for the coding block).

[0157] In the IBC-TM AMVP mode, candidates (e.g., up to 3 candidates) may be selected from the IBC-TM merge list. In an example, candidates (e.g., each of the up-to-3-selected-candidates) may be refined using the template matching method. The candidates (e.g., each of the up-to-3-selected-candidates) may be sorted according to their resulting template matching costs, for example. Some candidates (e.g., the 2 first candidates) may be considered in the motion estimation process.

[0158] With template matching refinement (e.g., template matching refinement for IBC-TM merge mode and/or AMVP mode), IBC block vectors may be constrained. For example, the IBC block vectors may be constrained to be integer and/or within a reference region (e.g., as shown in FIG. 6). In IBC-TM merge mode, refinements may be performed at integer precision, for example. In IBC-TM AMVP mode, refinement may be performed at integer precision or 4-pel precision, for example. In IBC-TM AMVP mode, refinement may be performed at integer precision or 4-pel precision, for example. depending on the AMVR value. Such a refinement may access (e.g., only access) samples without interpolation. The refined block vectors and the used template in each refinement step may respect the constraint of the reference region.

[0159] FIG. 8 shows an example reference area for IBC when CTU (m, n) is coded is shown. The "curr" block may denote the current CTU. The shaded blocks may denote the reference area. The white block may denote an invalid reference area. The IBC reference region may depend

on a current CU position. For example, the reference area for IBC may be extended to above CTU rows (e.g., two CTU rows above).

[0160] FIG. 9 illustrates an example reference area for IBC with coding tree unit (CTU) (m, n) being coded. The white blocks may denote an invalid reference area. In an example, for CTU (m, n) to be coded, the reference area may include CTUs with index (m-2, n-2)...(W, n-2), (0, n-1)...(W, n-1), (0, n)...(m, n), where W denotes the maximum horizontal index within the current tile, slice or picture. For example, when CTU size is 256, the reference area may include one CTU row above (e.g., be limited to one CTU row above). This setting may ensure that for CTU size being 128 or 256, IBC may use memory like that (e.g., not exceeding that). For example, the per-sample block vector search (e.g., local search) range may be limited to $[-(C \ll 1), C \gg 2]$ horizontally and $[-C, C \gg 2]$ vertically to adapt to the reference area extension, where C denotes the CTU size.

[0161] Possible MVD sign combinations may be sorted according to the template matching cost. An index corresponding to the true MVD sign may be derived and/or context coded. At the decoder side, the MVD signs may be derived. For example, the magnitude of MVD components may be parsed. The context coded MVD sign prediction index may be parsed. MV candidates may be built. For example, MV candidates may be built by creating combination between possible signs and absolute MVD value (e.g., and add it to the MV predictor). MVD sign prediction cost may be derived. For example, MVD sign prediction cost may be derived for each derived MV based on template matching cost and sort. The MVD sign prediction index may be used to pick a true MVD sign.

[0162] In an example, MVD sign prediction may be applied to inter AMVP, affine AMVP, MMVD and affine MMVD modes. In an example, wrap around motion compensation may be enabled. For example, when wrap around motion compensation is enabled, the MV candidate may be clipped with wrap around offset taken into consideration.

[0163] As disclosed herein, IntraTMP fusion, filtering, and sub-pixel information may be used for IBC merge mode.

[0164] For example, IntraTMP fusion may include a mode where multiple IntraTMP predictors (e.g., predictors described by block vectors) may be fused together. In an example, the fusion weights may be based on template cost. In an example, the fusion weights may be calculated using a regression model. In an example, this information may be unused for an IBC-block whose merge info refers to such a block.

[0165] In an example, fusion information (e.g., the same fusion information) may be used. For example, merge information may include the multiple predictors described by IntraTMP. For example, at the decoder side, if a merge index refers to an IntraTMP coded block, the same fusion

info may be used. For example, where multiple block vectors are considered, the predictors may be fused using the designated fusion method.

[0166] In an example, the fusion information may be translated to bidirectional IBC. For example, two block vectors may be extracted from an IntraTMP fusion block. Those blocks may include ones whose template costs are the least, for example. The block vectors (e.g., those two block vectors with least cost) may be considered as ones (e.g., the two ones) used for bi-directional prediction. This approach maintains the IBC merge mechanism. This approach may represent a new input added to the IBC merge mechanism.

[0167] IntraTMP filtering may be used. For example, IntraTMP prediction may be filtered (e.g., as learned from a reconstructed template). A syntax element may be used to indicate if the filtering is used. A flag may be signaled to indicate if a filtering process is used.

[0168] In the merge mode of IBC, if the merge candidate is IntraTMP with filtering enabled, the filter flag may be inherited. The filtering parameters may be re-used (e.g., copied from the merge candidate) and/or re-calculated from the current template. Recalculating the filtering parameters from the current template may represent an improvement in accuracy with additional complexity relative to re-using the filtering parameters.

[0169] IntraTMP may use a subpixel approach. For example, IntraTMP and/or IBC may use subpixel accuracy for block vectors. In IBC, quarter pixel accuracy may be used (e.g., only quarter pixel accuracy is used). In IntraTMP, 1/2, 1/4 and 3/4-pixel precision may be used, for example. In an example, `intra_tmp_sub_pel_direction_idx` may specify the sub-pixel direction index.

[0170] In an example, in merge mode, with a merge candidate being IntraTMP, the same sub-pixel information of IntraTMP may be used. Here, for example, the information about subpixel may be inherited from an IntraTMP candidate. To illustrate, the IBC block may use the same precision (1/2, 1/4 and 3/4) and the same direction.

[0171] In an example, in merge mode, with a merge candidate being IntraTMP, IntraTMP sub-pixel information may be translated to the IBC domain. Here, for example, the equivalent precision may be used. To illustrate, if subpixel is used in IntraTMP, 1/4 pixel precision may be used for IBC. The direction, here, may be neglected. With this method, the precision of IBC may be maintained (e.g., new candidates are added). Using the same sub-pixel information of the IntraTMP may provide better accuracy with some increase complexity relative to translating IntraTMP sub-pixel information to the IBC domain.

[0172] IntraTMP template mode may be used. During IntraTMP predictor search in ECM, various ways to search for a predictor may be used. For example, the predictor search may include top-only and left-only template region-based search. For example, multiple IntraTMP prediction candidates may be derived. For example, an index may be signaled to indicate which

candidate (e.g., the best candidate) is selected. For example, an index may be signaled to indicate the K best candidates issued from template search.

[0173] The type of template search associated with the selected candidate may be stored in a buffer (e.g., a dedicated buffer) at the encoder and/or the decoder side. The selected candidate may be propagated to future blocks, for example, in IBC mode. In IBC merge and/or AMVP mode, if the block used to derive the BV data of current block comes from an intraTMP search, the associated TM search type may be retrieved. This may be then re-used for the current IBC block for template matching based refinement of the derived block vector.

[0174] The approaches disclosed herein may be applied to IBC AMVP coding mode. For example, the approach may relate to the IBC BV predictor candidate list and/or the selection of a BV information predictor for a current block being coded in IBC AMVP mode. The AMVP candidate list may include a subset of the IBC merge list in ECM.

[0175] 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.

1. A video decoding method comprising:
obtaining, for a current block, an intra block copy (IBC) merge candidate list having a
5 candidate corresponding to intra-template fusion mode; and
determining to predict the current block based on the candidate corresponding to intra-
template fusion mode;
deriving a plurality of block vectors based on the candidate; and
decoding the current block based on the derived plurality of block vectors.
10
2. The video decoding method of claim 1, further comprising:
obtaining a first prediction block based on a first block vector of the derived plurality of
block vectors;
obtaining a second prediction block based on a second block vector of the derived plurality
15 of block vectors; and
determining a fused prediction block by fusing the first prediction block and the second
prediction block, wherein the current block is decoded based on the fused prediction block.
3. The video decoding method of claim 2, wherein the first prediction block and the second
20 prediction block are fused based on a fusion weight type and a fusion index associated with the
candidate.
4. The video decoding method of claim 1, further comprising:
based on filtering being enabled for the candidate corresponding to intra-template fusion
25 mode, obtaining a set of filtering parameters associated with the candidate; and
filtering a reference block of the current block based on the set of filtering parameters
associated with the candidate, wherein the current block is decoded based on the filtered
reference block.
- 30 5. The video decoding method of claim 1, further comprising:
determining sub-pixel information of the candidate corresponding to intra-template fusion
mode, wherein the plurality of block vectors are derived based on the sub-pixel information.
6. The video decoding method of claim 1, further comprising:
35 determining sub-pixel information of the candidate corresponding to intra-template fusion
mode; and

based on the sub-pixel information of the candidate indicating that subpixel is used in intra-template matching, determining to derive the plurality of block vectors at a quarter pixel precision.

5

7. The video decoding method of claim 1, further comprising:
obtaining a template mode search type associated with the candidate; and
refining the plurality of block vectors based on the template mode search type, wherein the current block is decoded based on the plurality of refined block vectors.

10

8. A video encoding method comprising:
obtaining, for a current block, an intra block copy (IBC) merge candidate list having a candidate corresponding to intra-template fusion mode; and
determining to predict the current block based on the candidate corresponding to intra-
15 template fusion mode;
deriving a plurality of block vectors based on the candidate; and
encoding the current block based on the derived plurality of block vectors.

15

9. The video encoding method of claim 8, further comprising:
20 obtaining a first prediction block based on a first block vector of the derived plurality of block vectors;
obtaining a second prediction block based on a second block vector of the derived plurality of block vectors; and
determining a fused prediction block by fusing the first prediction block and the second
25 prediction block, wherein the current block is encoded based on the fused prediction block.

20

25

10. The video encoding method of claim 9, wherein the first prediction block and the second prediction block are fused based on a fusion weight type and a fusion index associated with the candidate.

30

11. The video encoding method of claim 8, further comprising:
based on filtering being enabled for the candidate corresponding to intra-template fusion mode, obtaining a set of filtering parameters associated with the candidate; and
filtering a reference block of the current block based on the set of filtering parameters
35 associated with the candidate, wherein the current block is encoded based on the filtered reference block.

35

12. The video encoding method of claim 8, further comprising:
determining sub-pixel information of the candidate corresponding to intra-template fusion mode, wherein the plurality of block vectors are derived based on the sub-pixel information.

5

13. The video encoding method of claim 8, further comprising:
determining sub-pixel information of the candidate corresponding to intra-template fusion mode; and

10 based on the sub-pixel information of the candidate indicating that subpixel is used in intra-template matching, determining to derive the plurality of block vectors at a quarter pixel precision.

14. The video encoding method of claim 8, further comprising:
obtaining a template mode search type associated with the candidate; and
15 refining the plurality of block vectors based on the template mode search type, wherein the current block is decoded based on the plurality of refined block vectors.

15. A device for video decoding, the device comprising:
a processor configured to:
20 obtain, for a current block, an intra block copy (IBC) merge candidate list having a candidate corresponding to intra-template fusion mode; and
determine to predict the current block based on the candidate corresponding to intra-template fusion mode;
derive a plurality of block vectors based on the candidate; and
25 decode the current block based on the derived plurality of block vectors.

16. The device of claim 15, the processor further configured to:
obtain a first prediction block based on a first block vector of the derived plurality of block vectors;

30 obtain a second prediction block based on a second block vector of the derived plurality of block vectors; and

determine a fused prediction block by fusing the first prediction block and the second prediction block, wherein the current block is decoded based on the fused prediction block.

35 17. The device of claim 16, wherein the first prediction block and the second prediction block are fused based on a fusion weight type and a fusion index associated with the candidate.

18. The device of claim 15, the processor further configured to:
based on filtering being enabled for the candidate corresponding to intra-template fusion mode, obtain a set of filtering parameters associated with the candidate; and
5 filter a reference block of the current block based on the set of filtering parameters associated with the candidate, wherein the current block is decoded based on the filtered reference block.
19. The device of claim 15, the processor further configured to:
10 determine sub-pixel information of the candidate corresponding to intra-template fusion mode, wherein the plurality of block vectors are derived based on the sub-pixel information.
20. The device of claim 15, the processor further configured to:
determine sub-pixel information of the candidate corresponding to intra-template fusion
15 mode; and
based on the sub-pixel information of the candidate indicating that subpixel is used in intra-template matching, determine to derive the plurality of block vectors at a quarter pixel precision.
21. The device of claim 15, the processor further configured to:
obtain a template mode search type associated with the candidate; and
refine the plurality of block vectors based on the template mode search type, wherein the
current block is decoded based on the plurality of refined block vectors.
22. A device for video encoding, the device comprising:
a processor configured to:
obtain, for a current block, an intra block copy (IBC) merge candidate list having a
candidate corresponding to intra-template fusion mode; and
determine to predict the current block based on the candidate corresponding to intra-
30 template fusion mode;
derive a plurality of block vectors based on the candidate; and
encode the current block based on the derived plurality of block vectors.
23. The device of claim 22, the processor further configured to:
35 obtain a first prediction block based on a first block vector of the derived plurality of block vectors;

obtain a second prediction block based on a second block vector of the derived plurality of block vectors; and

5 determine a fused prediction block by fusing the first prediction block and the second prediction block, wherein the current block is encoded based on the fused prediction block.

24. The device of claim 23, wherein the first prediction block and the second prediction block are fused based on a fusion weight type and a fusion index associated with the candidate.

10 25. The device of claim 22, the processor further configured to:
based on filtering being enabled for the candidate corresponding to intra-template fusion mode, obtain a set of filtering parameters associated with the candidate; and
filter a reference block of the current block based on the set of filtering parameters associated with the candidate, wherein the current block is encoded based on the filtered
15 reference block.

26. The device of claim 22, the processor further configured to:
determine sub-pixel information of the candidate corresponding to intra-template fusion mode, wherein the plurality of block vectors are derived based on the sub-pixel information.

20 27. The device of claim 22, the processor further configured to:
determine sub-pixel information of the candidate corresponding to intra-template fusion mode; and
based on the sub-pixel information of the candidate indicating that subpixel is used in
25 intra-template matching, determine to derive the plurality of block vectors at a quarter pixel precision.

28. The device of claim 22, the processor further configured to:
obtain a template mode search type associated with the candidate; and
30 refine the plurality of block vectors based on the template mode search type, wherein the current block is decoded based on the plurality of refined block vectors.

29. 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
35 according to any one of claims 1-14 when executed by a processor.

30. Video data comprising information representative of the encoded current block generated according to the method of one of claims 8-14.

100

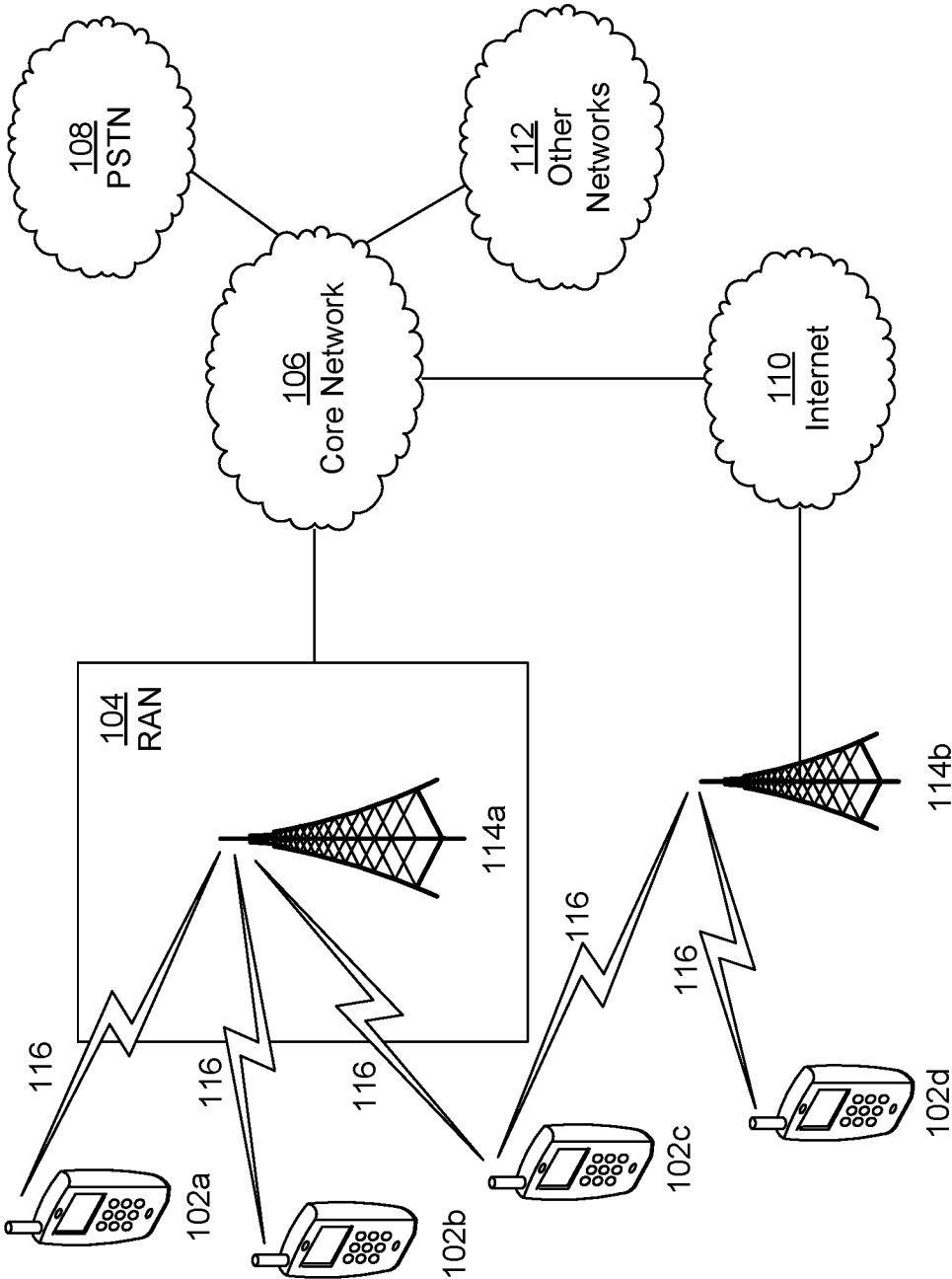


FIG. 1A

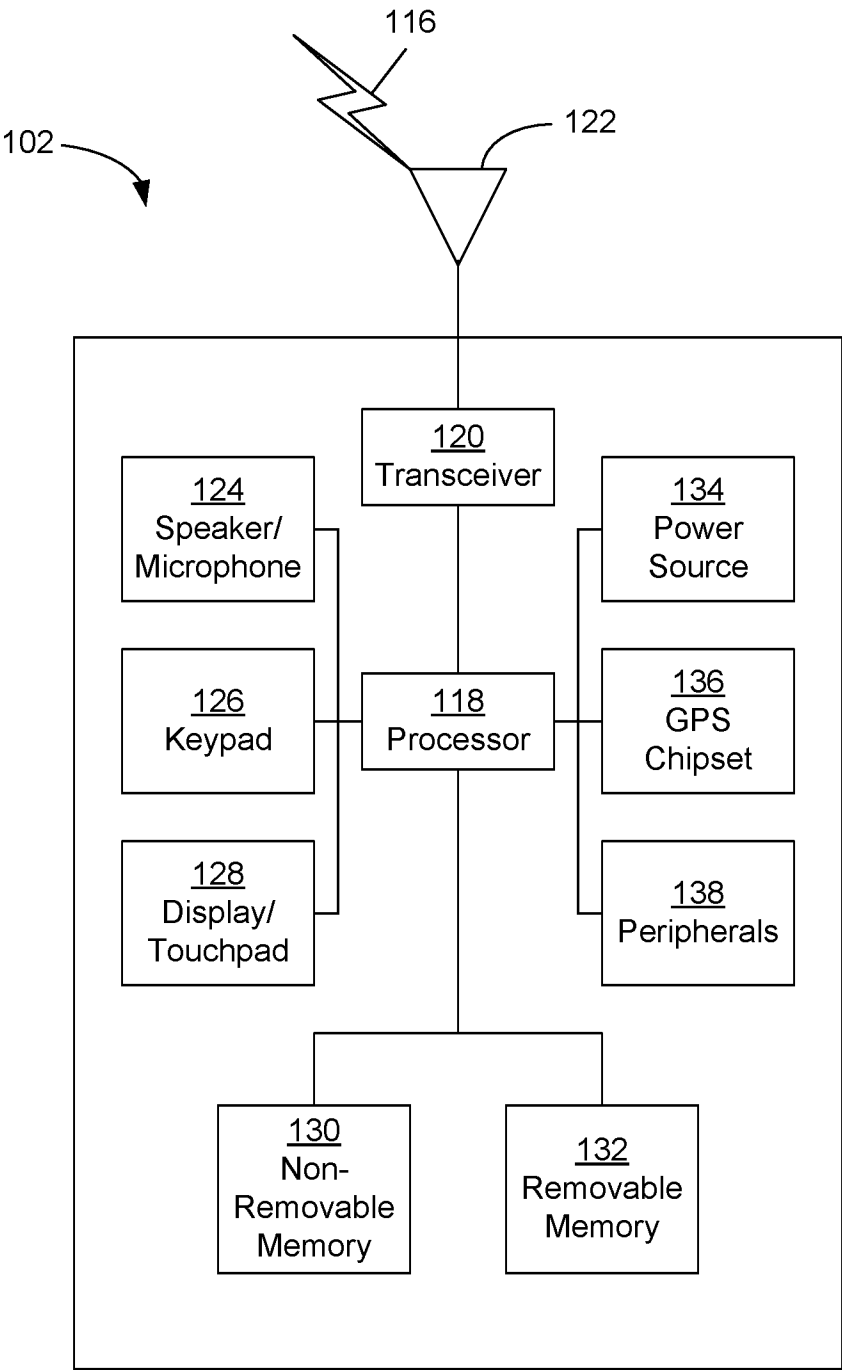


FIG. 1B

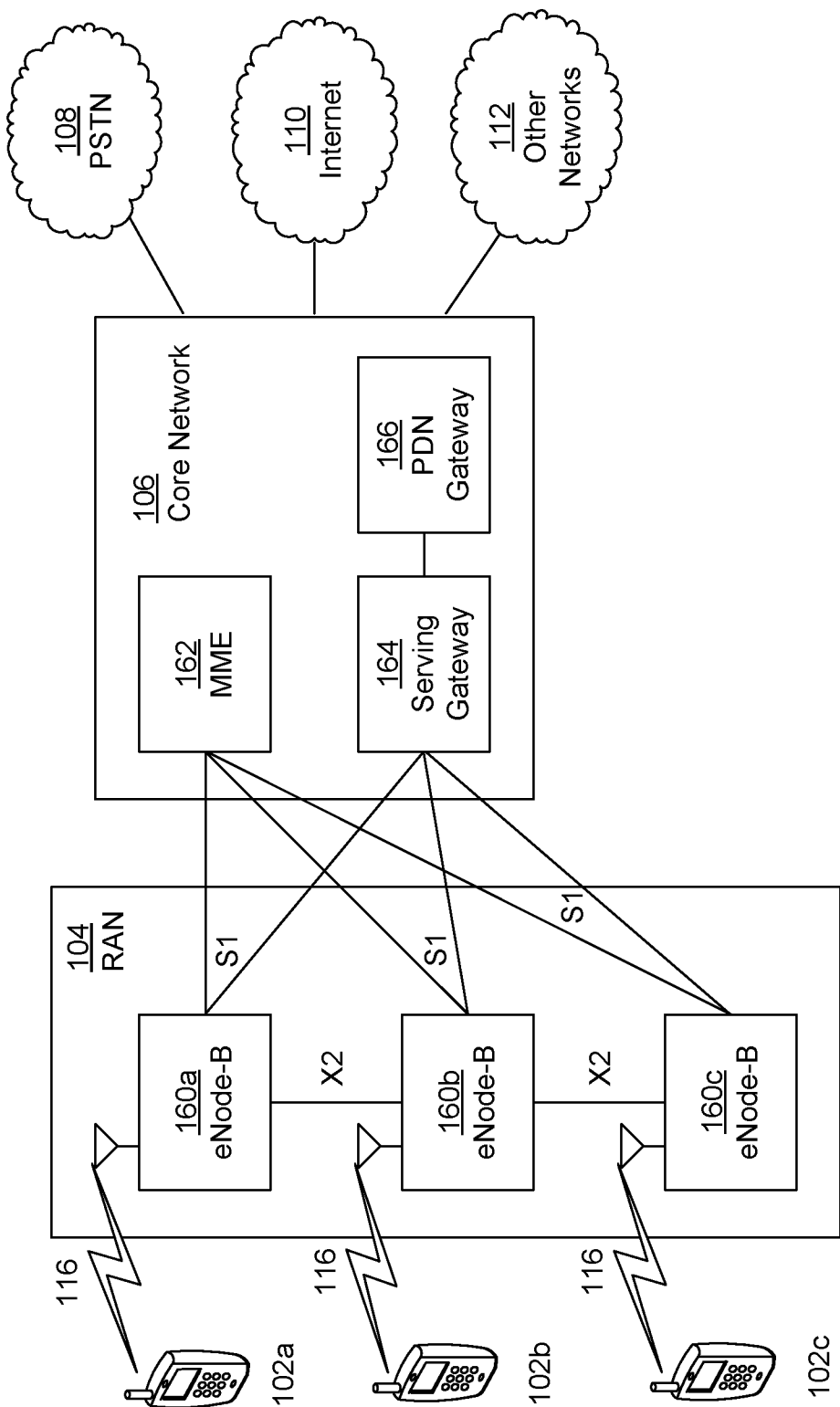


FIG. 1C

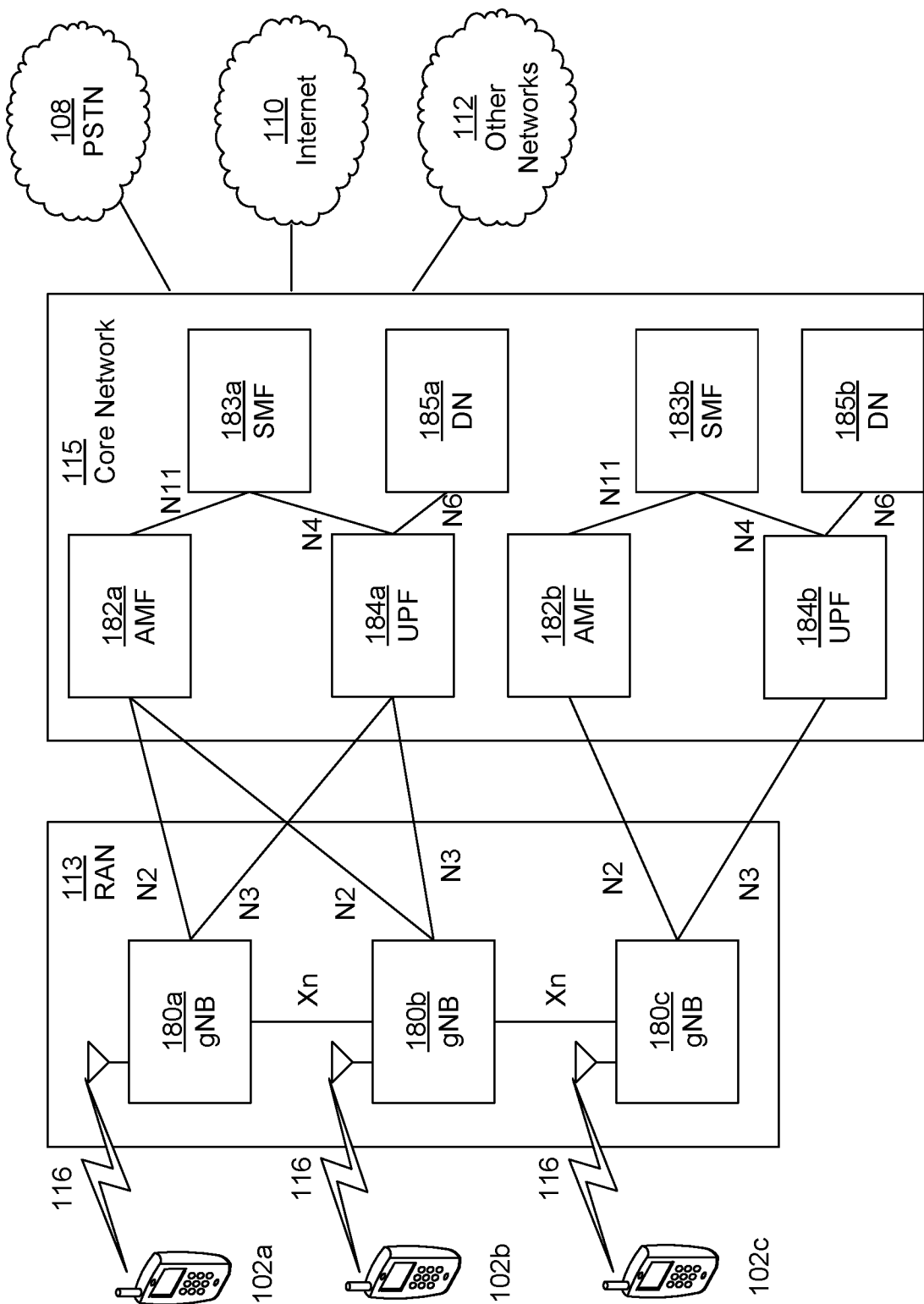


FIG. 1D

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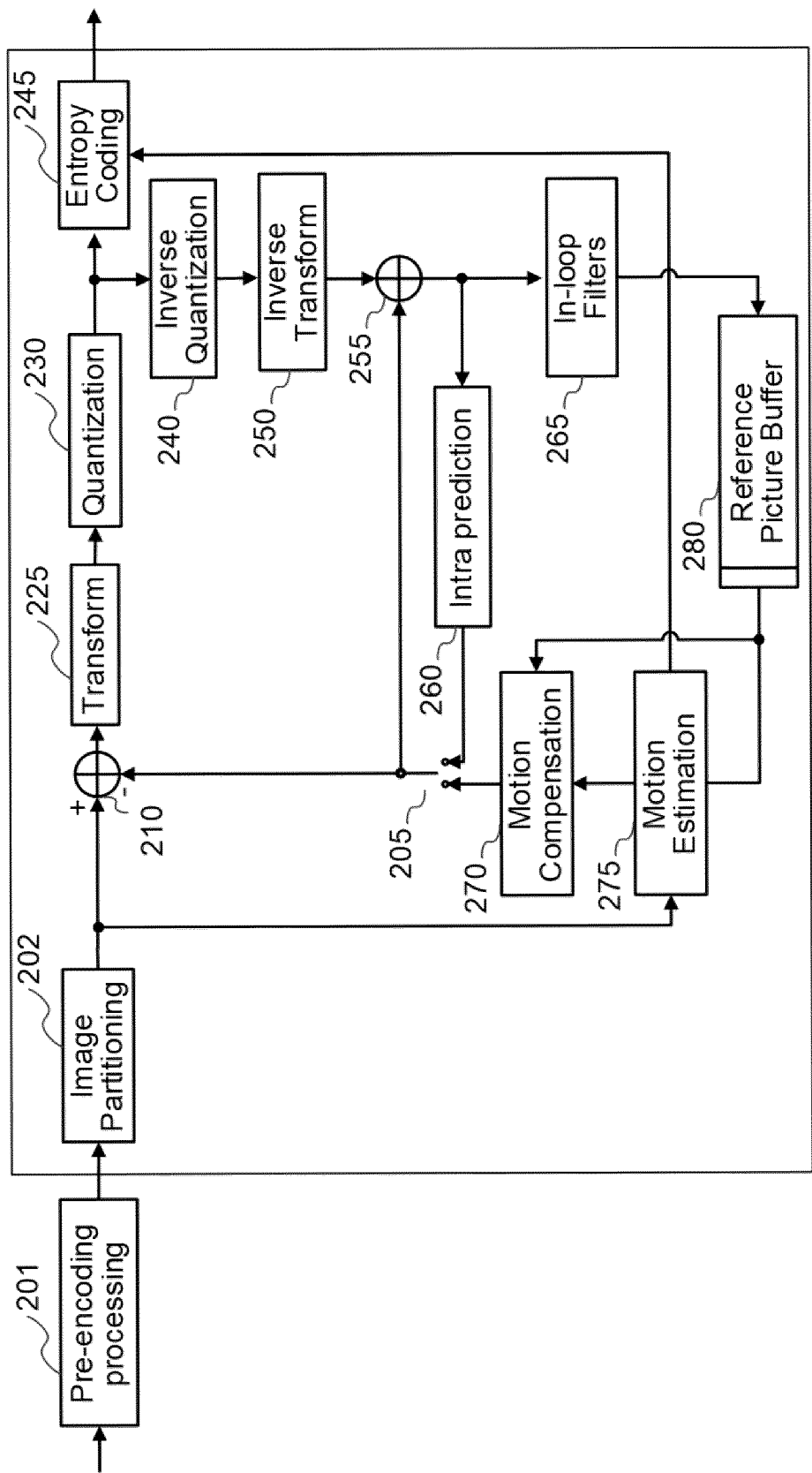


FIG. 2

300

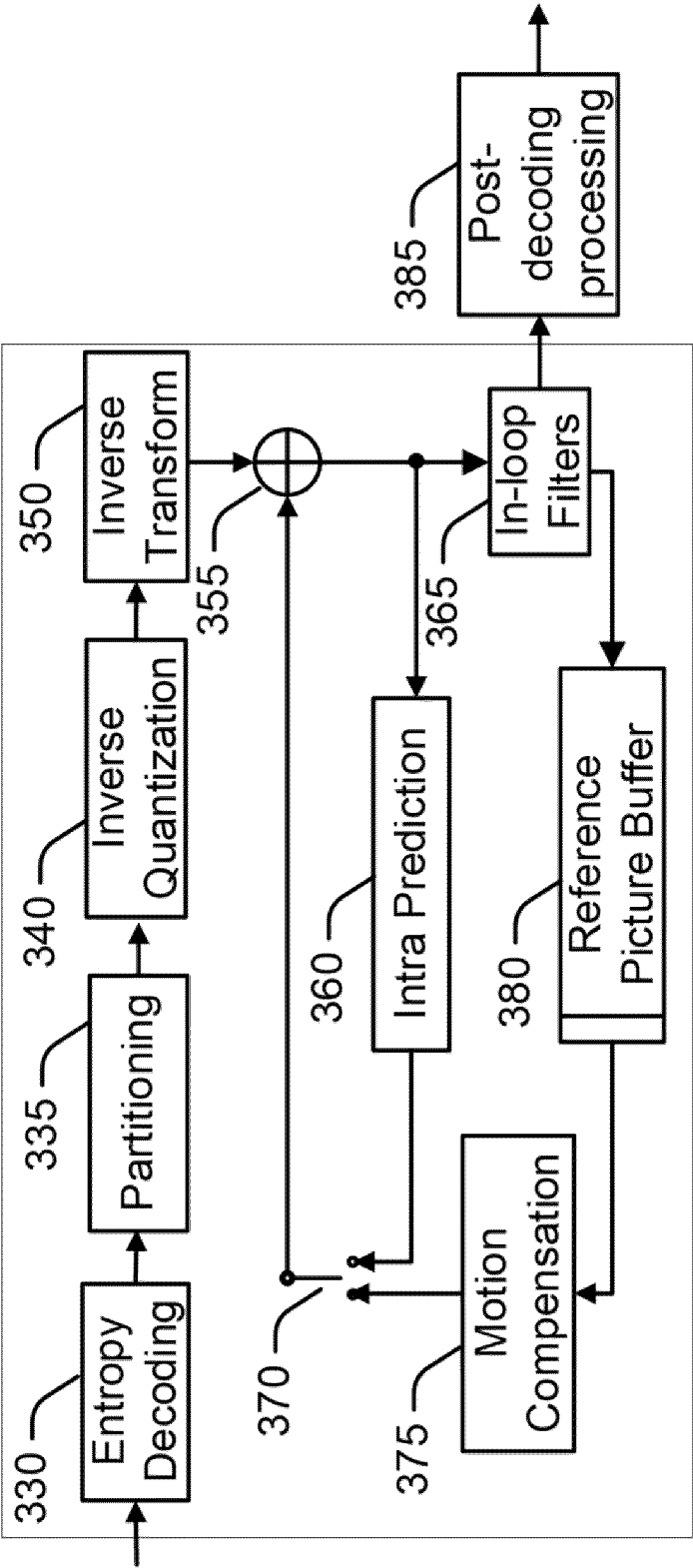


FIG. 3

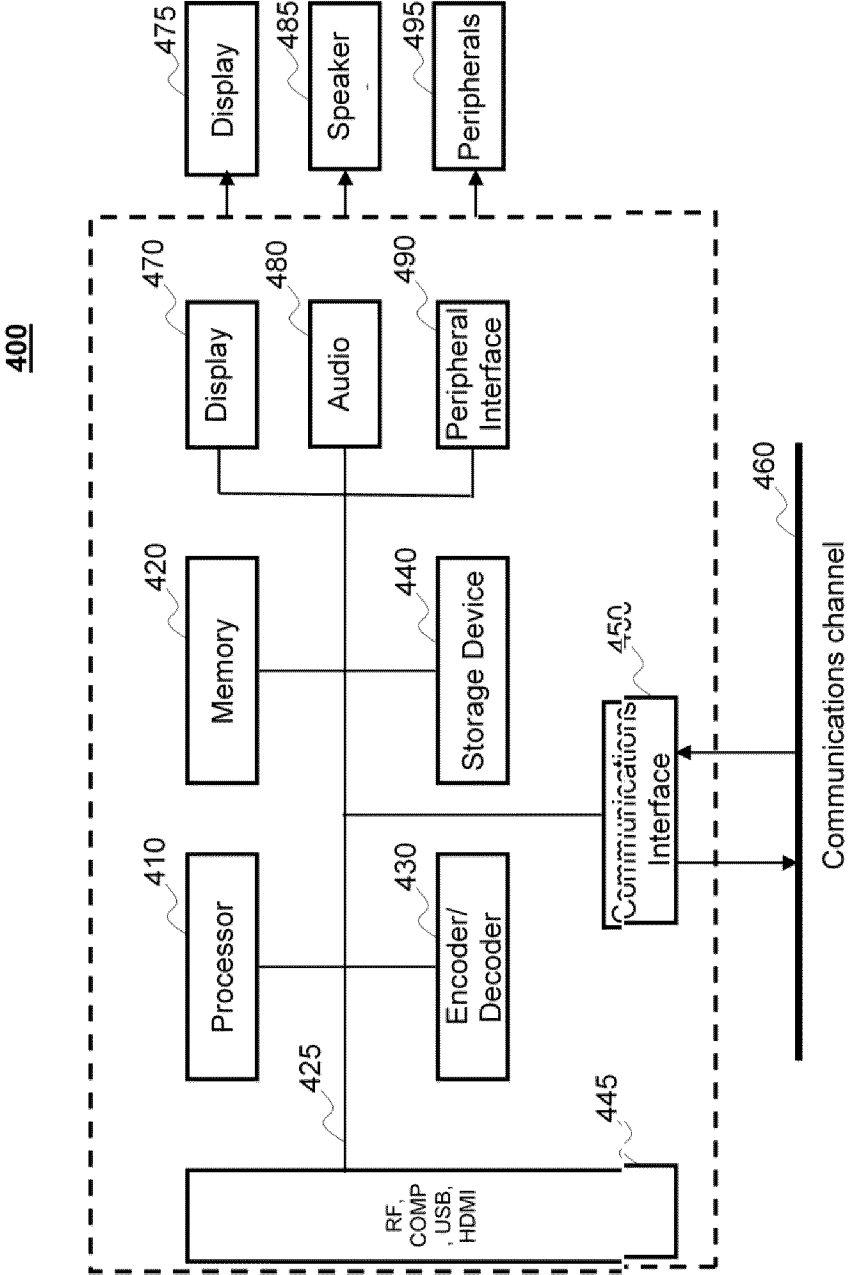
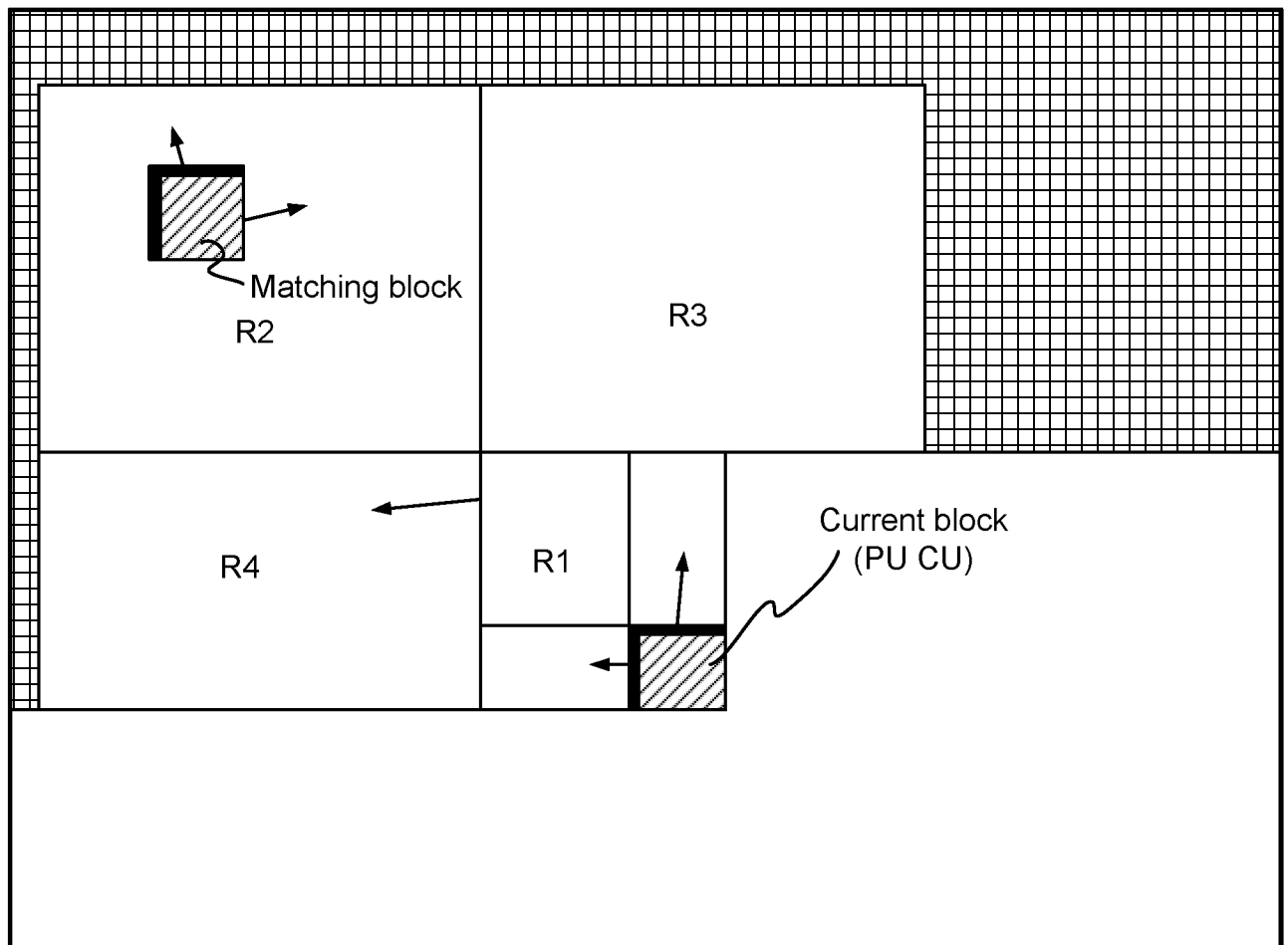


FIG. 4

**FIG. 5**

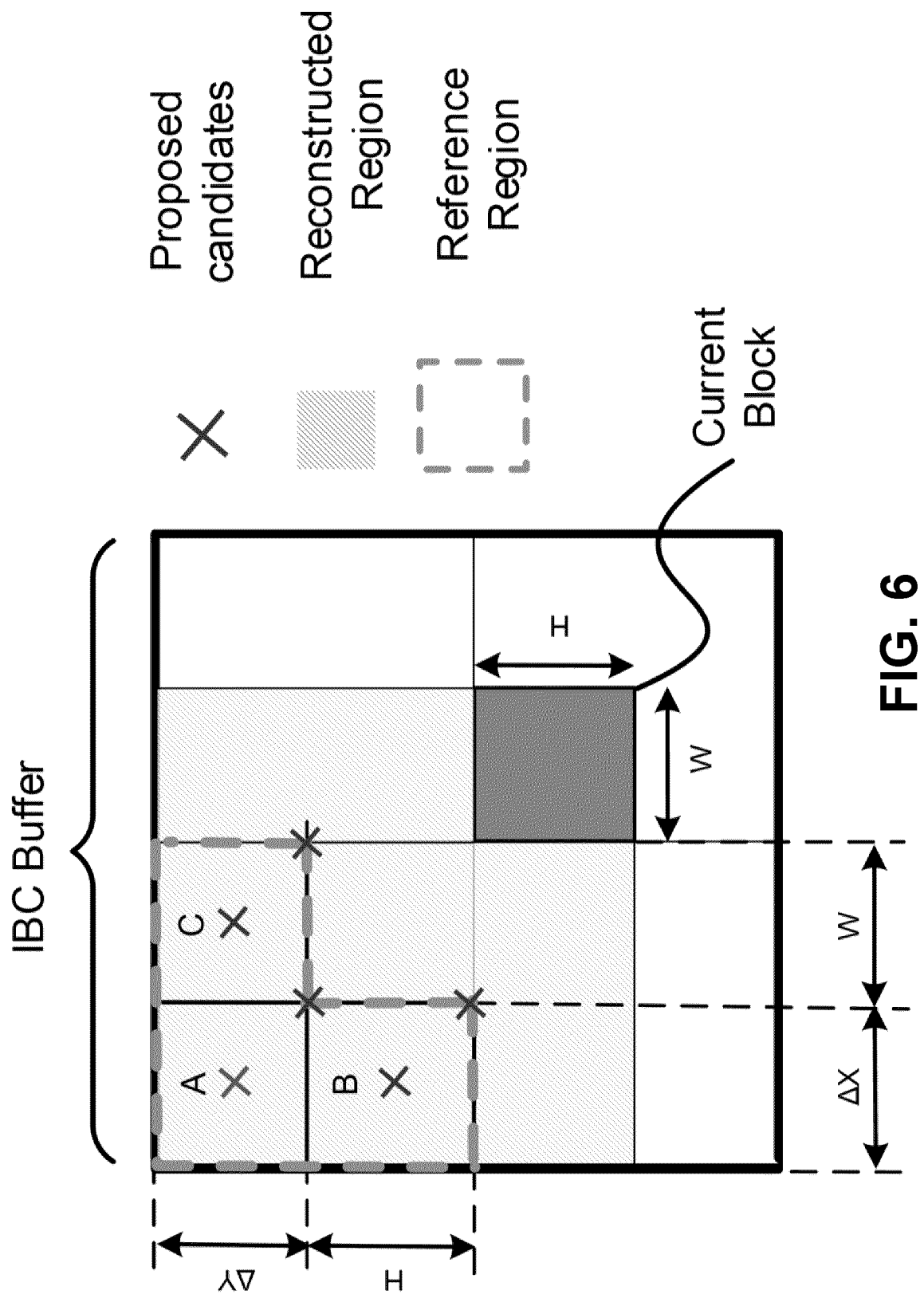
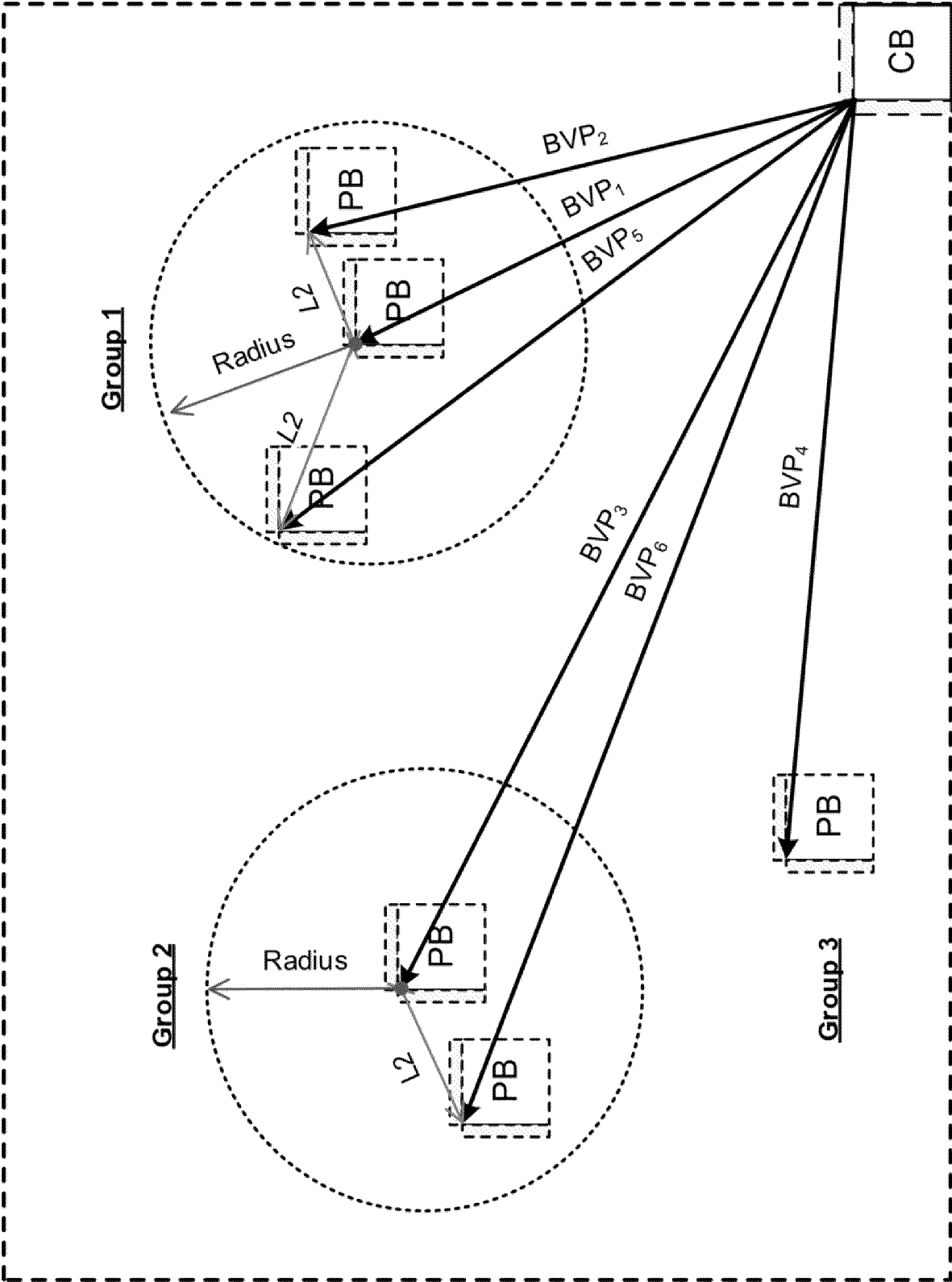


FIG. 6

FIG. 7



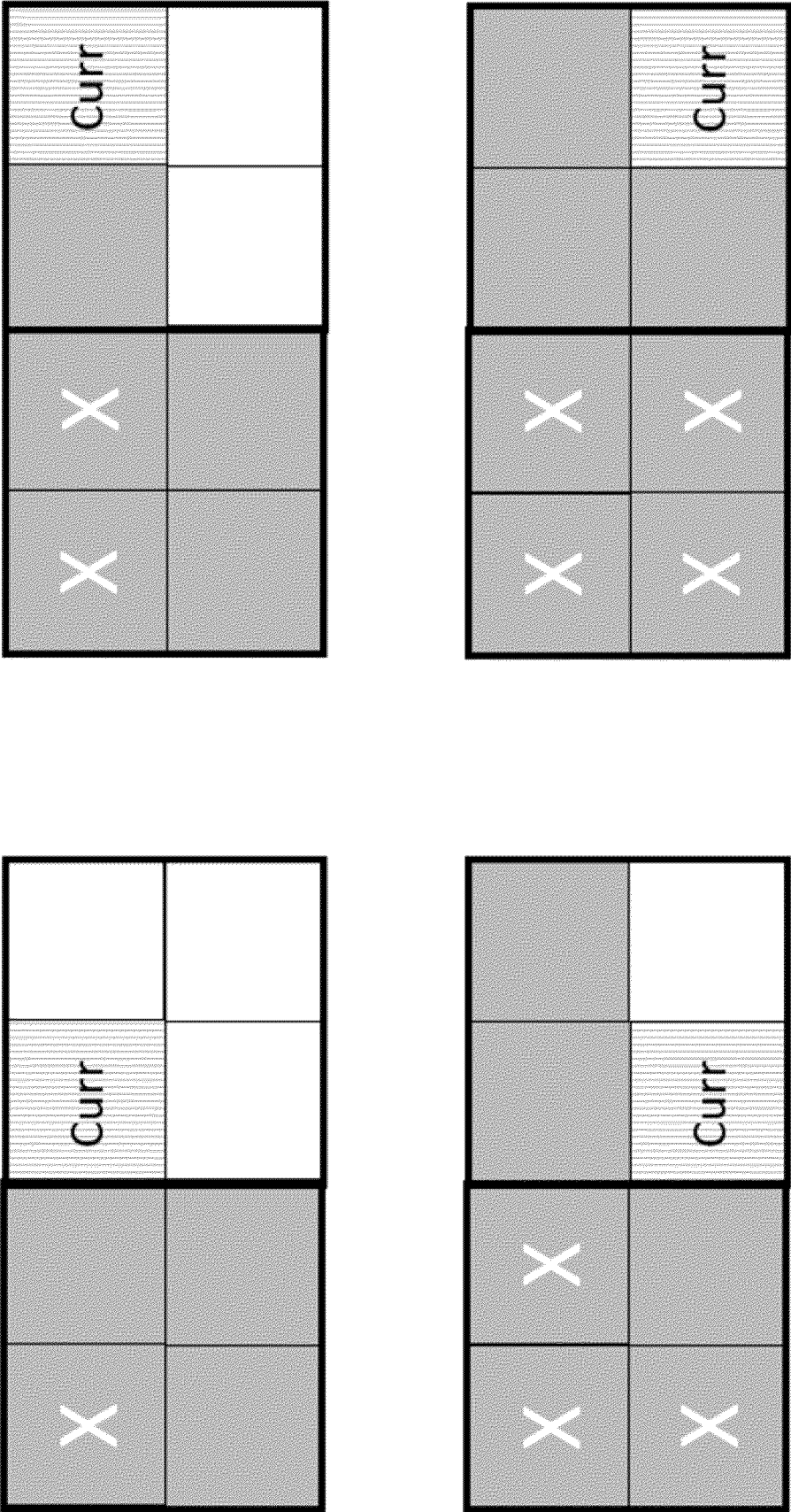


FIG. 8

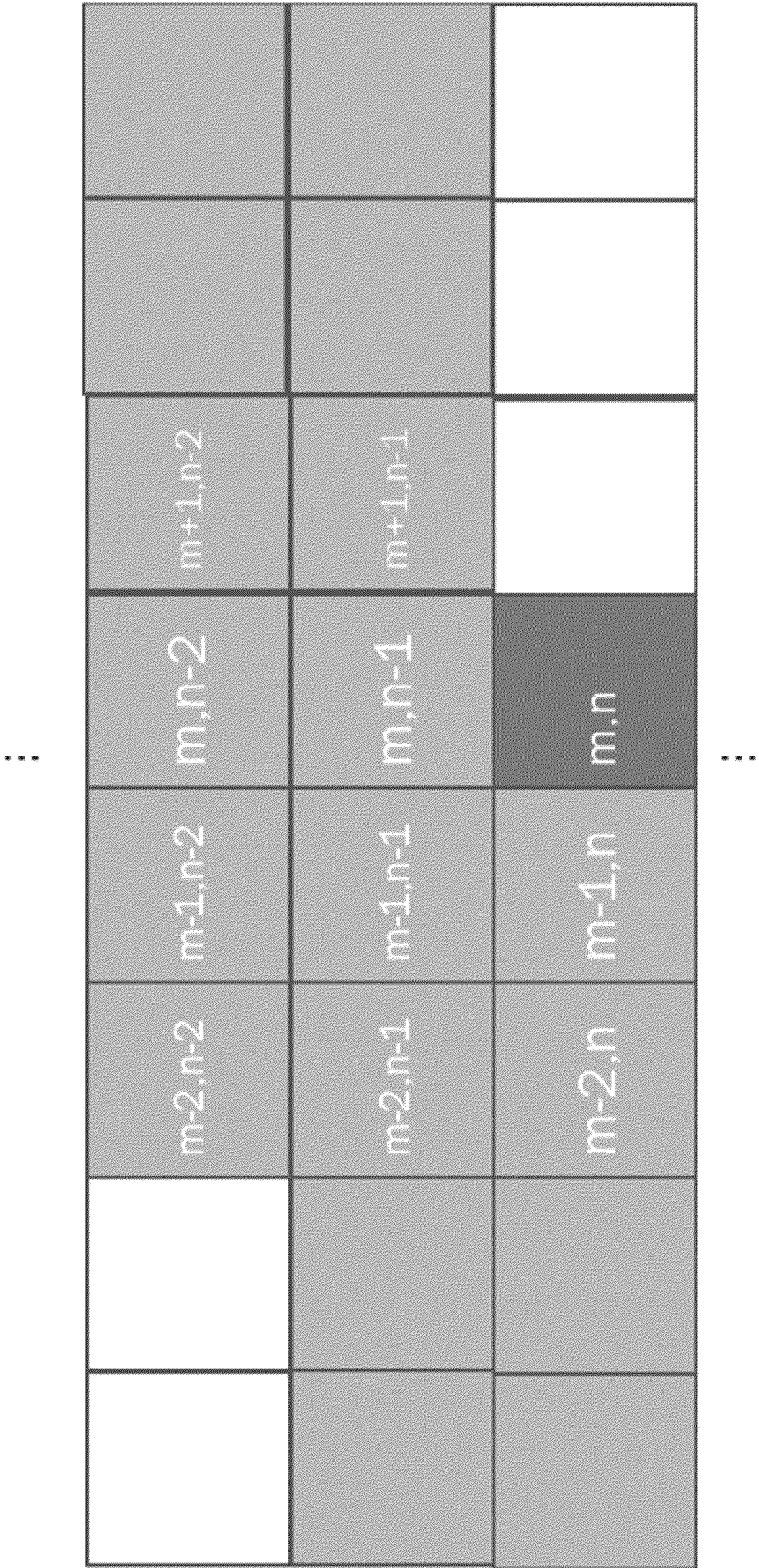


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/066198

A. CLASSIFICATION OF SUBJECT MATTER INV. H04N19/105 H04N19/176 H04N19/593 H04N19/70 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		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	NASER (INTERDIGITAL) K ET AL: "AHG12: IntraTMP with Merge Candidates", 32. JVET MEETING; 20231013 - 20231020; HANNOVER; (THE JOINT VIDEO EXPLORATION TEAM OF ISO/IEC JTC1/SC29/WG11 AND ITU-T SG.16), , no. JVET-AF0137 6 October 2023 (2023-10-06), XP030312232, Retrieved from the Internet: URL:p, applicantshttps://jvet-experts.org/doc_end _user/documents/32_Hannover/wg11/JVET-AF01 37-v1.zip JVET-AF0137.docx [retrieved on 2023-10-06] the whole document ----- -/-	1,8,15, 22,29,30
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 8 July 2024		Date of mailing of the international search report 29/07/2024
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Cakiroglu Garton, S

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2024/066198

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Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	WO 2023/046127 A1 (BEIJING BYTEDANCE NETWORK TECH CO LTD [CN]; BYTEDANCE INC [US]) 30 March 2023 (2023-03-30) paragraphs [02.8], [2.27] -----	1,8,15, 22,29,30
A	J-Y HUO ET AL: "EE2-1.16: A Fusion method of Intra Template Matching Prediction(Intra TMP)", 30. JVET MEETING; 20230421 - 20230428; ANTALYA; (THE JOINT VIDEO EXPLORATION TEAM OF ISO/IEC JTC1/SC29/WG11 AND ITU-T SG.16), , no. JVET-AD0116 ; m62754 20 April 2023 (2023-04-20), XP030308761, Retrieved from the Internet: URL:https://jvet-experts.org/doc_end_user/documents/30_Antalya/wg11/JVET-AD0116-v2.zip JVET-AD0116-v2.docx [retrieved on 2023-04-20] abstract paragraph [0002] -----	1-30

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2024/066198

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Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	ZHANG (OPPO) L ET AL: "EE2-1.11: Intra template matching prediction fusion", 30. JVET MEETING; 20230421 - 20230428; ANTALYA; (THE JOINT VIDEO EXPLORATION TEAM OF ISO/IEC JTC1/SC29/WG11 AND ITU-T SG.16), , no. JVET-AD0072 ; m62690 17 April 2023 (2023-04-17), XP030308663, Retrieved from the Internet: URL:https://jvet-experts.org/doc_end_user/documents/30_Antalya/wg11/JVET-AD0072-v2.zip ip JVET-AD0072-v2.docx [retrieved on 2023-04-17] the whole document -----	1-30

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2024/066198

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2023046127	A1	30-03-2023	NONE
