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(54) **TEMPLATE BASED MOST PROBABLE MODE LIST REORDERING**

(71) Applicant: **InterDigital CE Patent Holdings, SAS**, Paris (FR)

(72) Inventors: **Karam Naser**, Mouazé (FR); **Thierry Dumas**, Rennes (FR); **Franck Galpin**, Thorigne-Fouillard (FR); **Kevin Reuzé**, Rennes (FR)

(73) Assignee: **InterDigital CE Patent Holdings, SAS**, Paris (FR)

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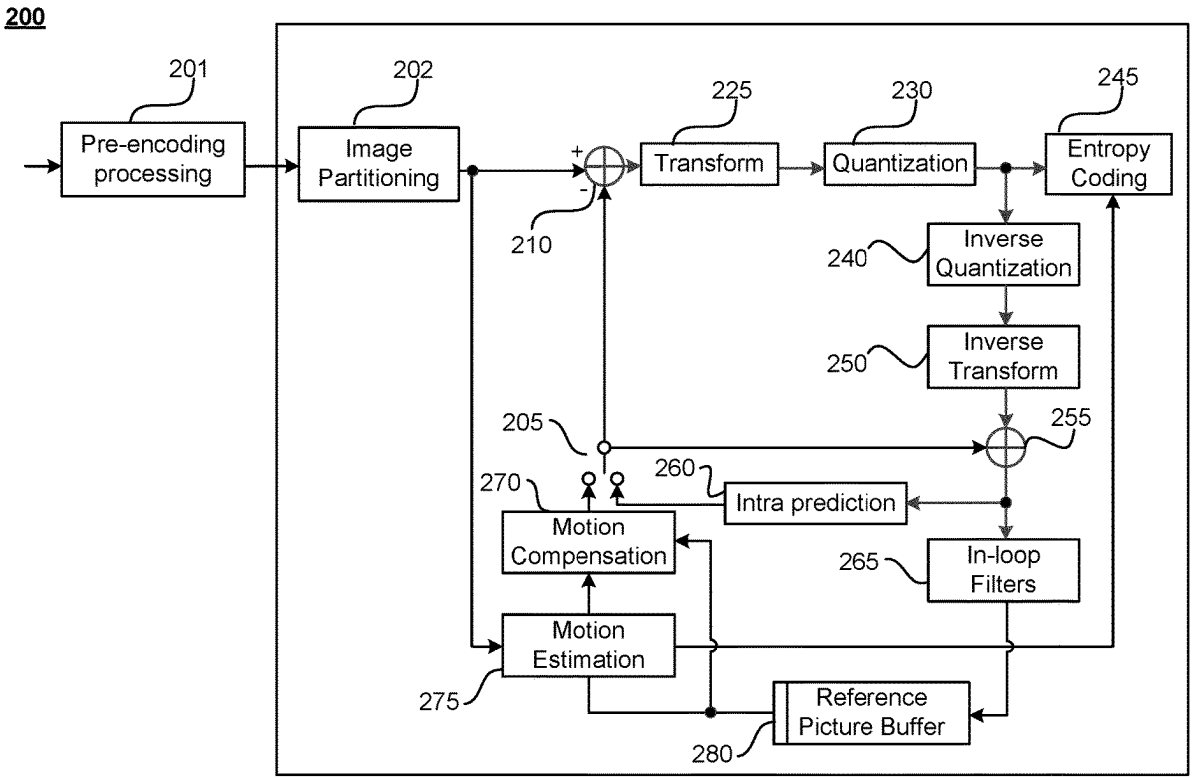
(57) **ABSTRACT**

Systems, methods, and instrumentalities are disclosed herein for the field of video coding. Examples herein may focus on the most probable mode (MPM) list. In examples, a video decoder device and/or a video encoder device may generate an MPM list for a current block. The encoder and/or decoder may reorder the MPM based on a reordering process for each mode of the MPM list. The decoder may perform prediction for the current block based on the reordered MPM list. The encoder may encoder the current block based on the reordered MPM list.



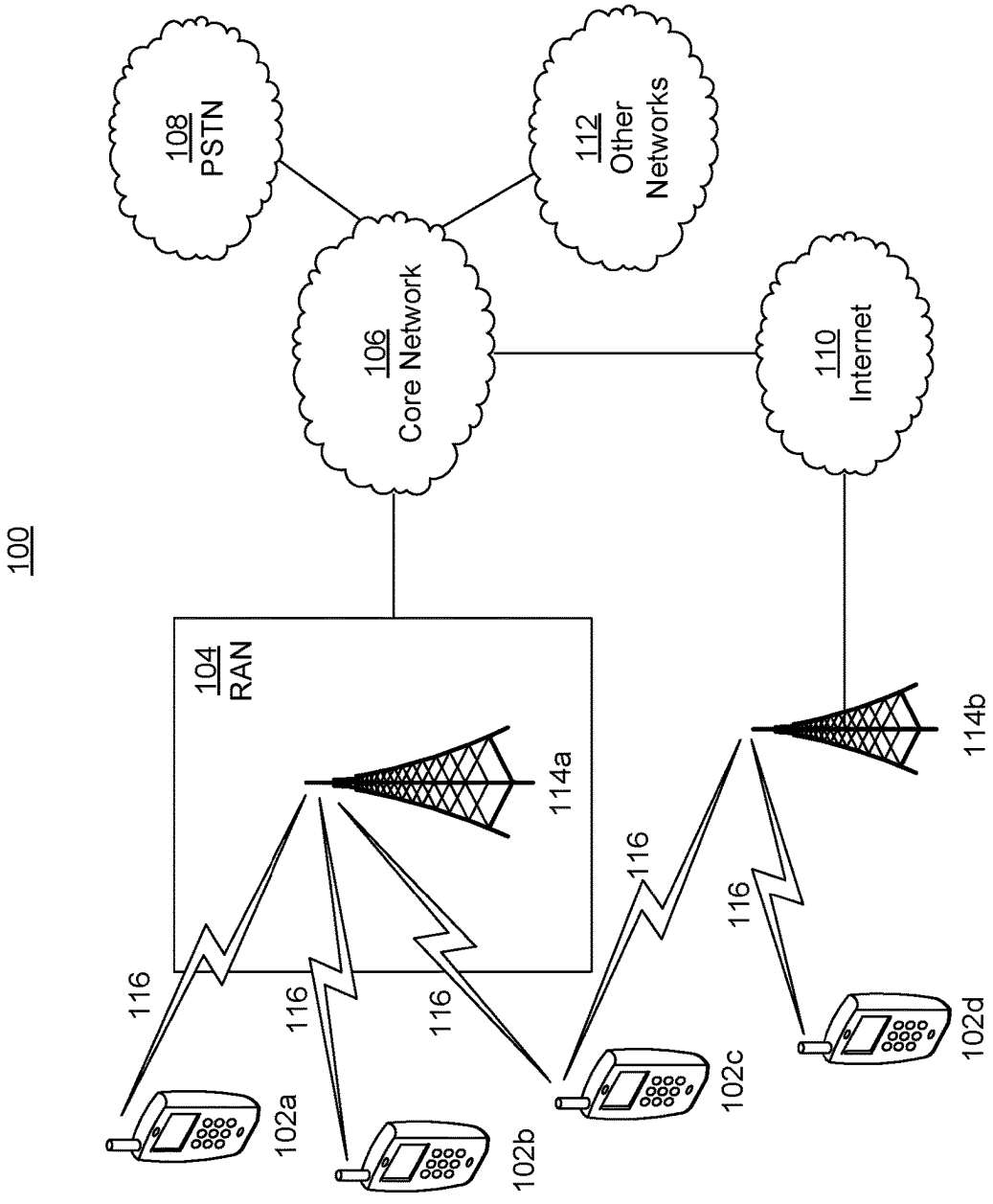

100
108 PSTN
112 Other Networks
106 Core Network
110 Internet
104 RAN
114a
114b
116
116
116
116
116
102a
102b
102c
102d

FIG. 1A

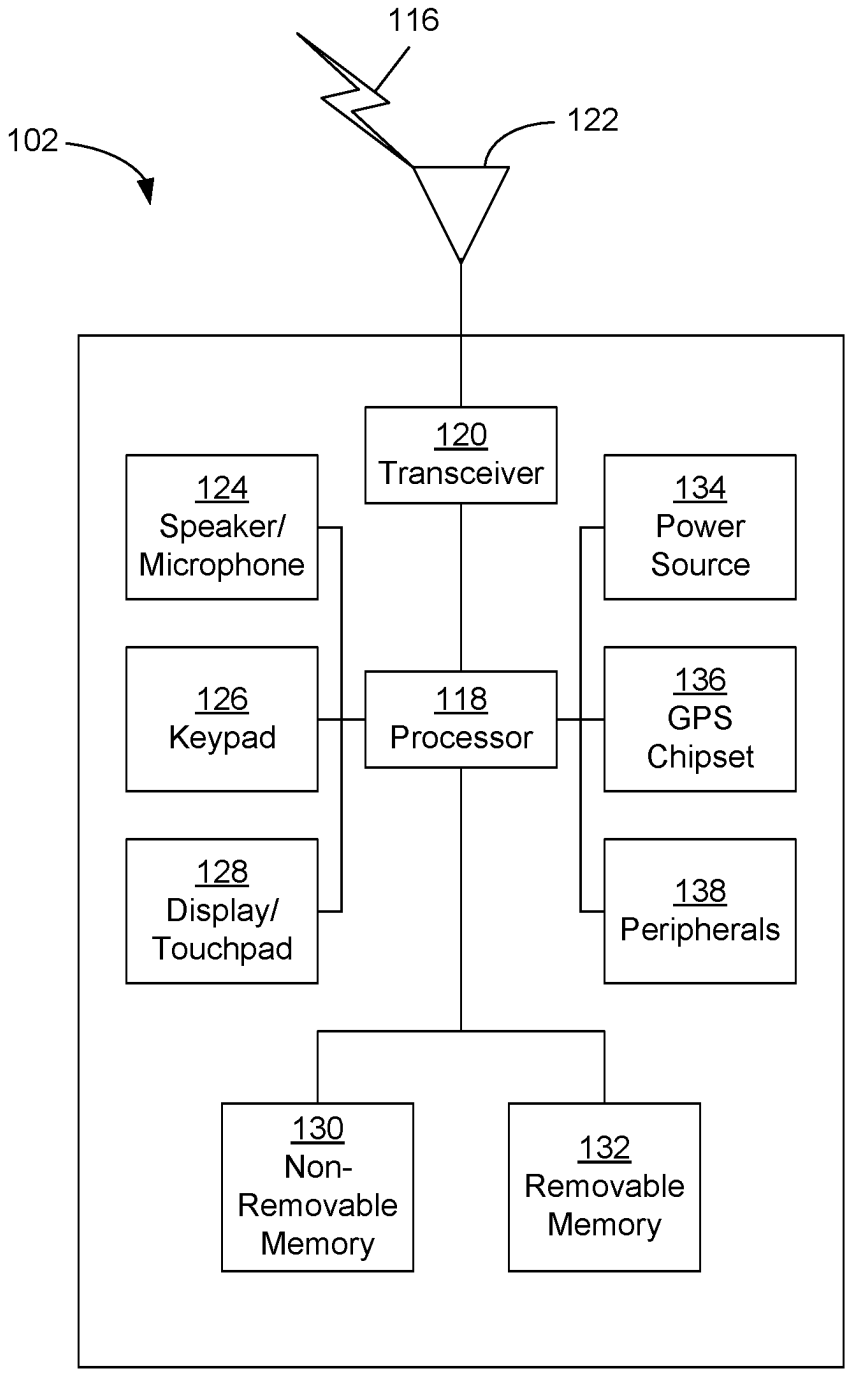

116
122
102
120
Transceiver
124
Speaker/
Microphone
134
Power
Source
126
Keypad
118
Processor
136
GPS
Chipset
128
Display/
Touchpad
138
Peripherals
130
Non-
Removable
Memory
132
Removable
Memory

FIG. 1B

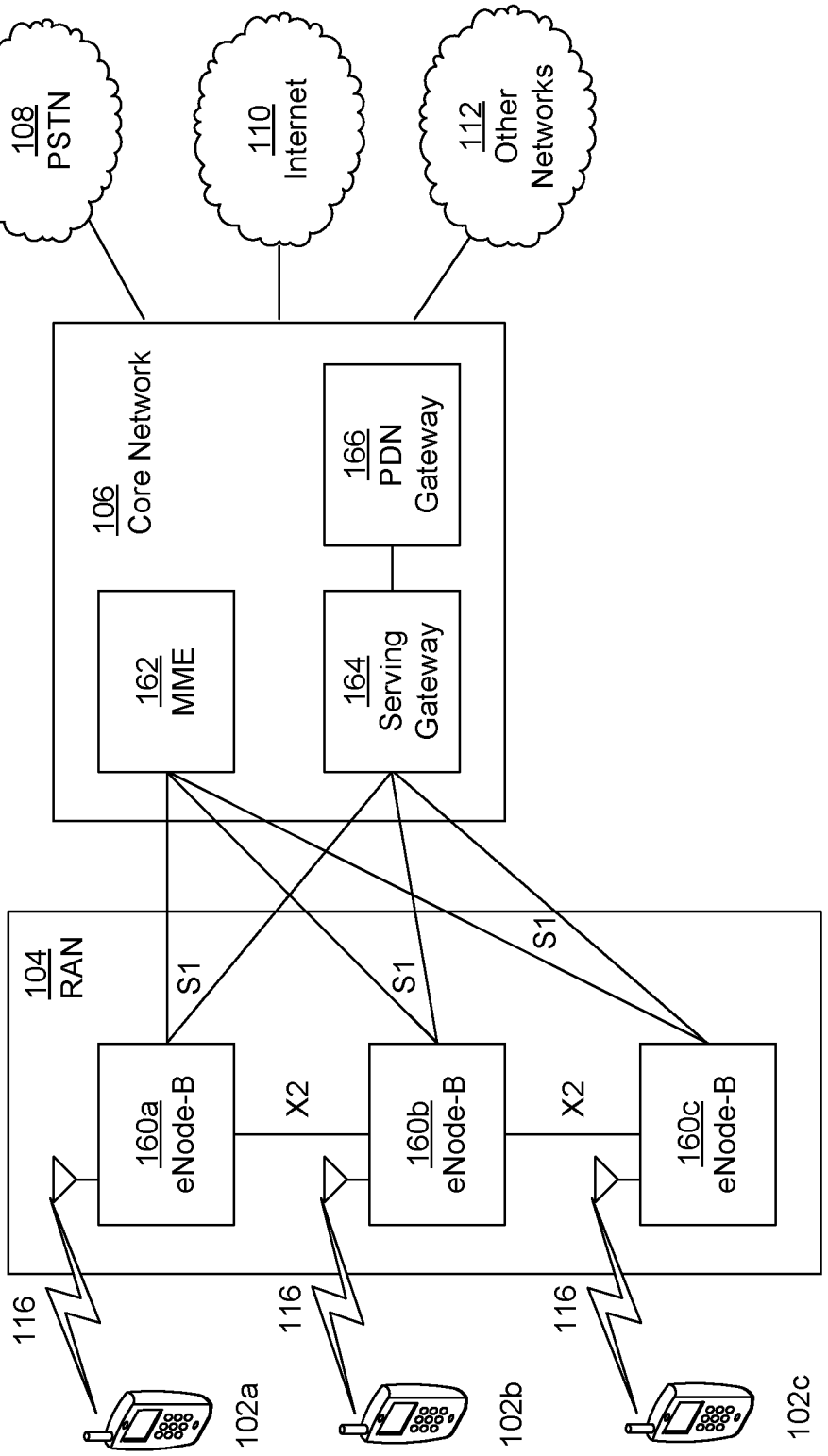

108 PSTN
110 Internet
112 Other Networks
106 Core Network
166 PDN Gateway
162 MME
164 Serving Gateway
104 RAN
S1
S1
S1
160a eNode-B
160b eNode-B
160c eNode-B
X2
X2
116
116
116
102a
102b
102c

FIG. 1C

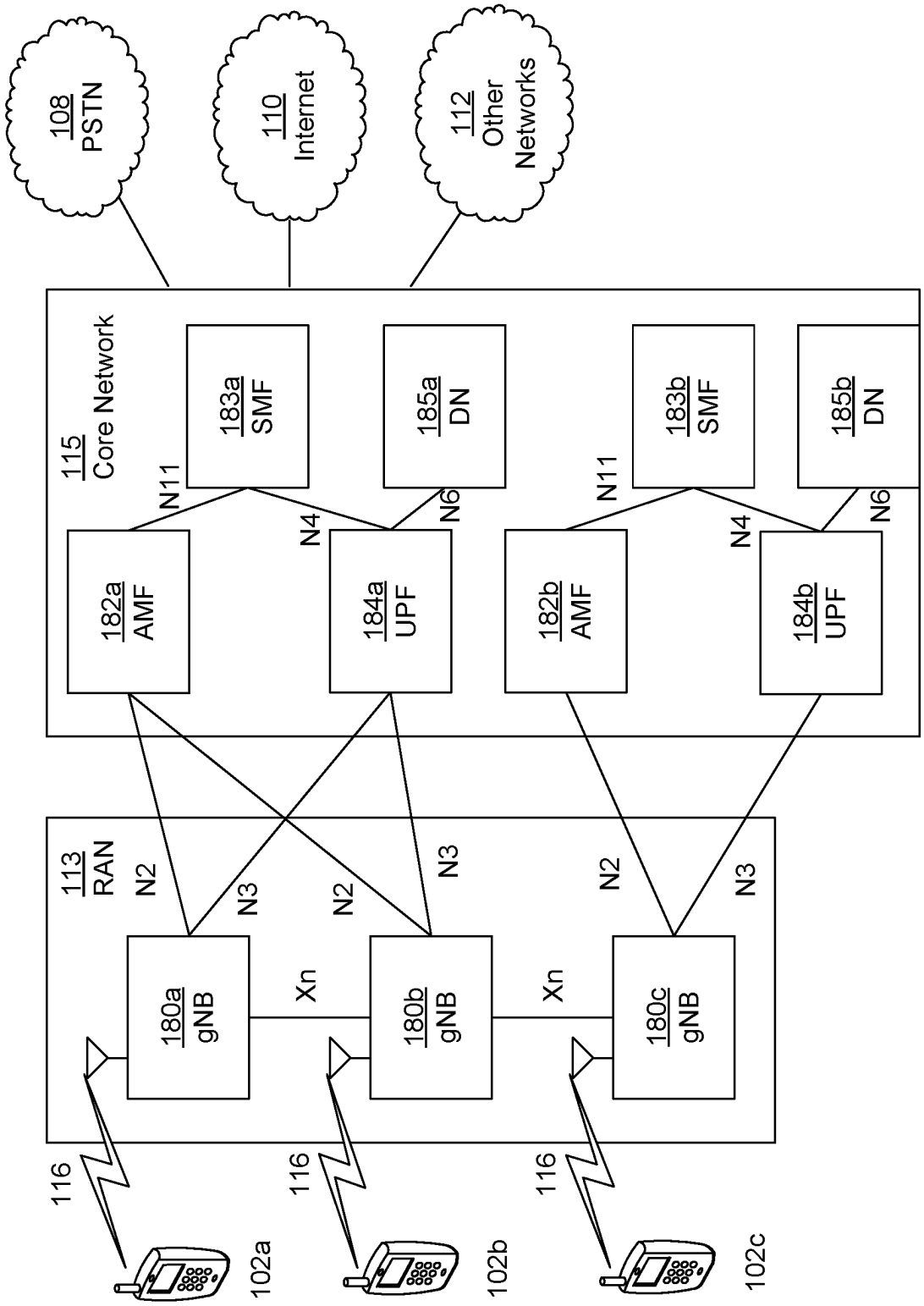

108 PSTN
110 Internet
112 Other Networks
115 Core Network
183a SMF
185a DN
183b SMF
185b DN
N11
N4
N6
182a AMF
184a UPF
182b AMF
184b UPF
113 RAN
N2
N3
180a gNB
180b gNB
180c gNB
Xn
116
102a
102b
102c

FIG. 1D

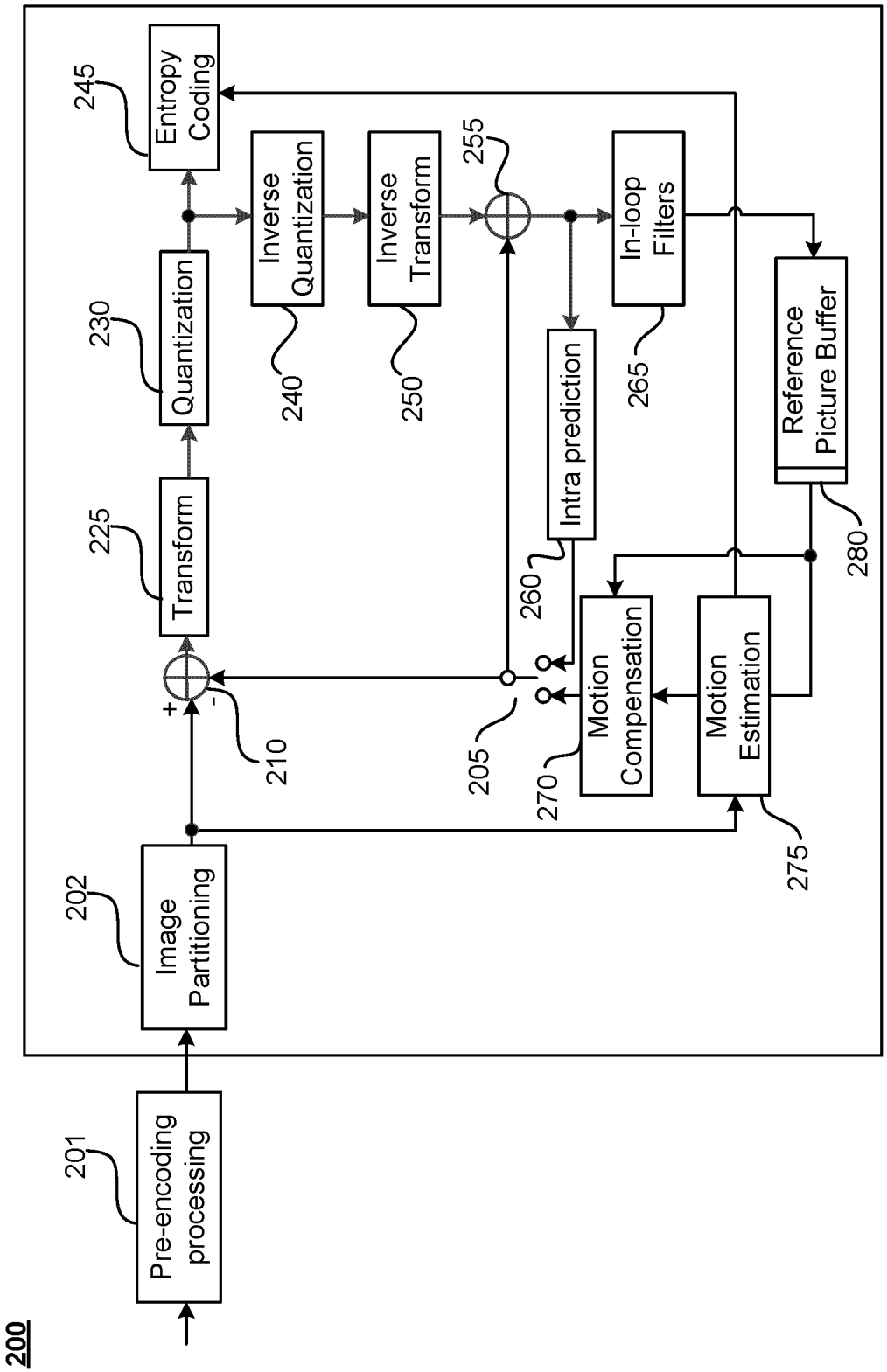

200
Pre-encoding processing
201
Image Partitioning
202
Transform
225
Quantization
230
Entropy Coding
245
Inverse Quantization
240
Inverse Transform
250
In-loop Filters
265
Reference Picture Buffer
280
Intra prediction
260
Motion Compensation
270
Motion Estimation
275
210
205
255
+
-

FIG. 2

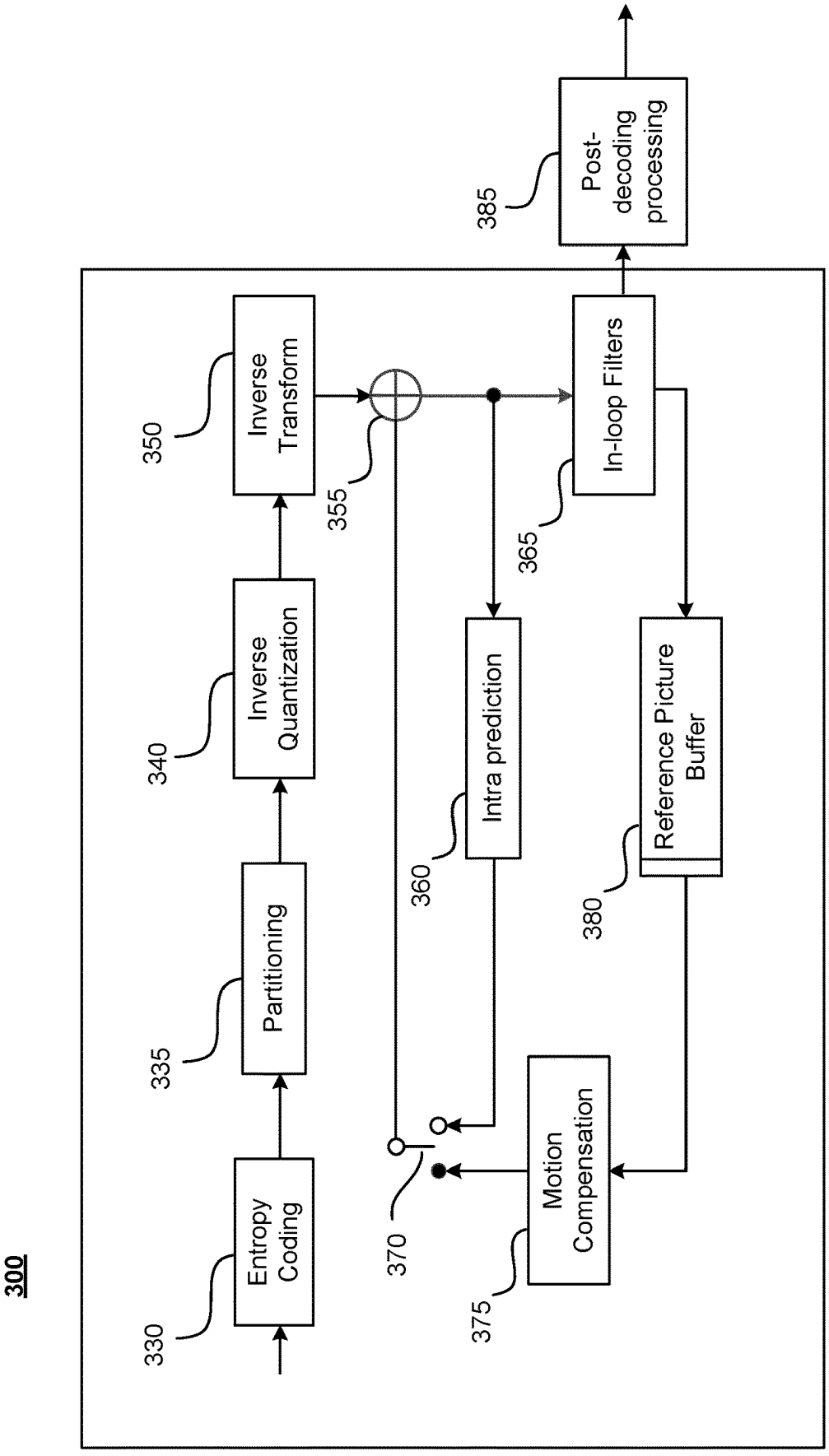

300
Entropy Coding
330
Partitioning
335
Inverse Quantization
340
Inverse Transform
350
355
In-loop Filters
365
Post-decoding processing
385
Intra prediction
360
Reference Picture Buffer
380
Motion Compensation
375
370

FIG. 3

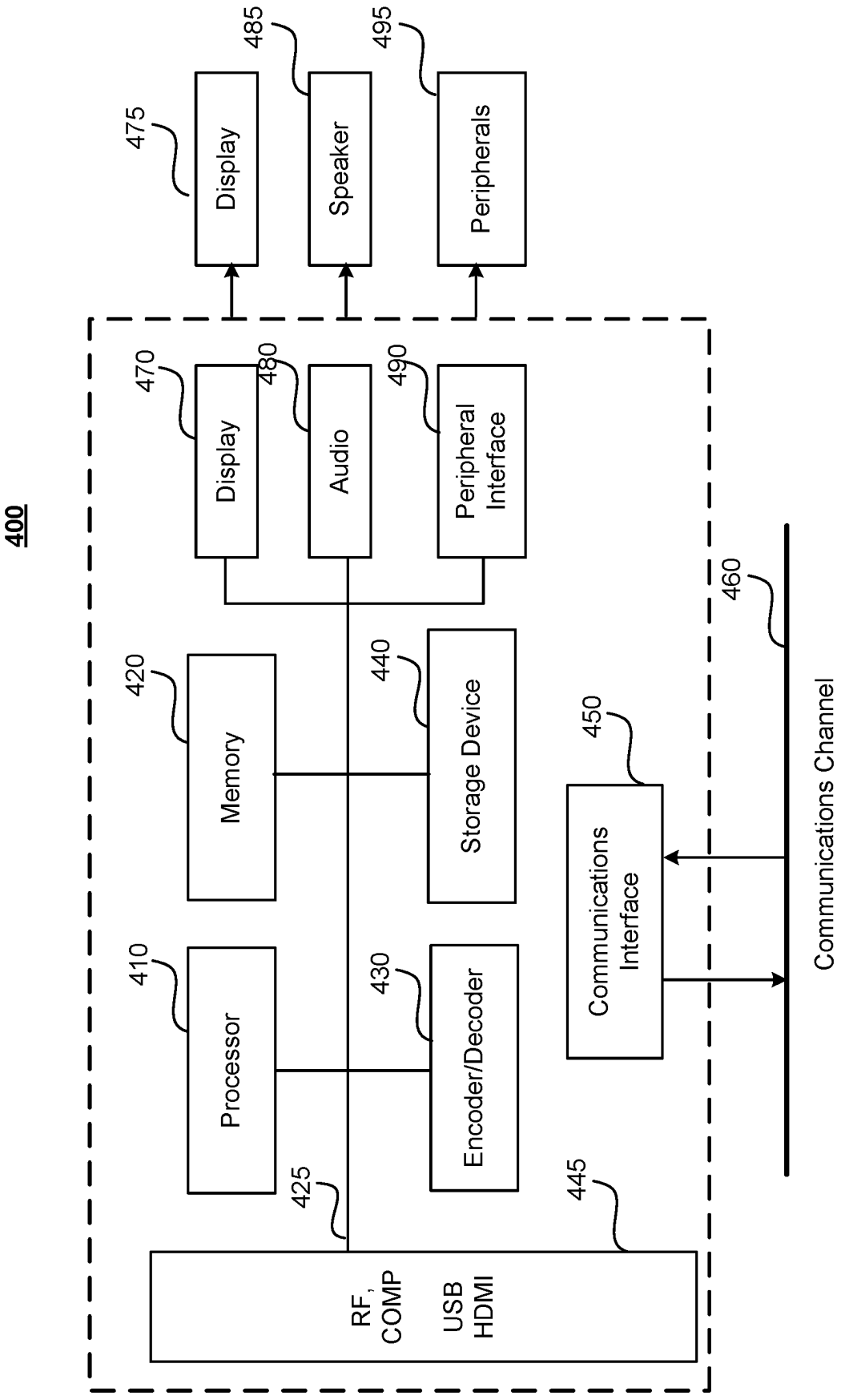

400
475
Display
485
Speaker
495
Peripherals
470
Display
480
Audio
490
Peripheral Interface
420
Memory
440
Storage Device
450
Communications Interface
460
Communications Channel
410
Processor
430
Encoder/Decoder
425
445
RF, COMP
USB HDMI

FIG. 4

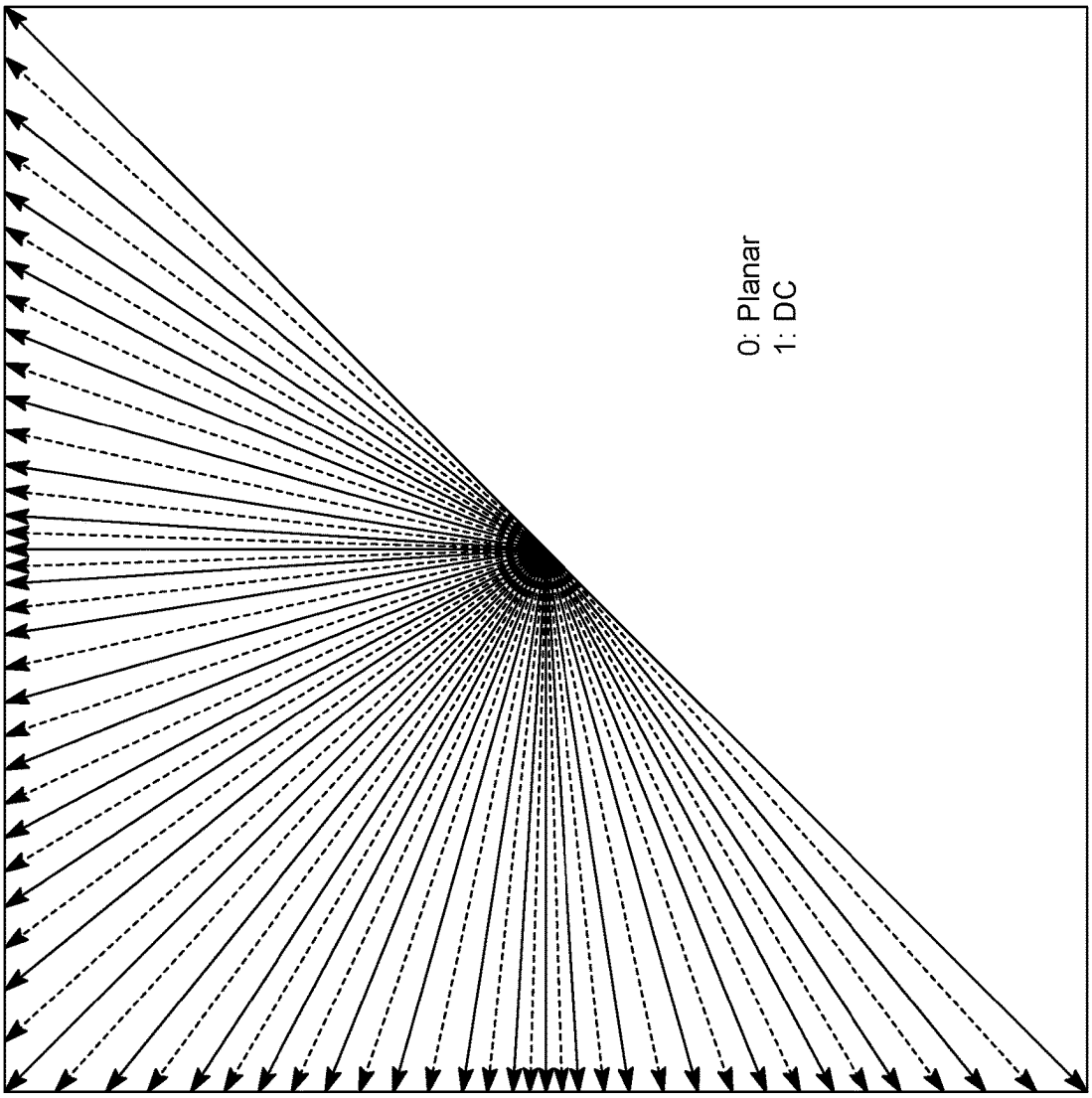
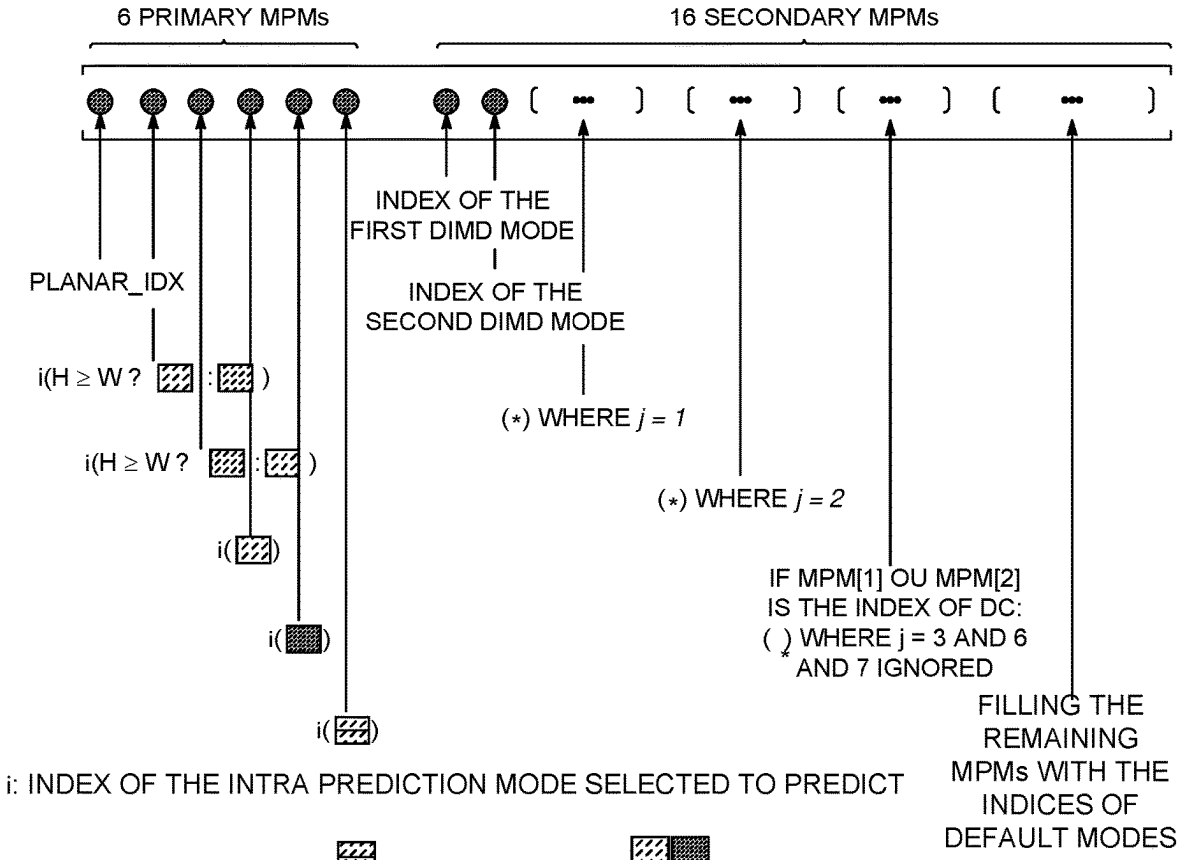
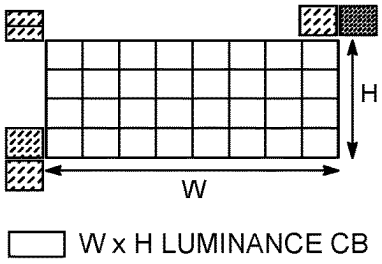


FIG. 5


6 PRIMARY MPMs
16 SECONDARY MPMs
INDEX OF THE FIRST DIMD MODE
INDEX OF THE SECOND DIMD MODE
PLANAR_IDX
i(H ≥ W ? :)
i(H ≥ W ? :)
i( )
i( )
i( )
(*) WHERE j = 1
(*) WHERE j = 2
IF MPM[1] OU MPM[2] IS THE INDEX OF DC: ( ) WHERE j = 3 AND 6 AND 7 IGNORED
FILLING THE REMAINING MPMs WITH THE INDICES OF DEFAULT MODES
i: INDEX OF THE INTRA PREDICTION MODE SELECTED TO PREDICT


H
W
W x H LUMINANCE CB

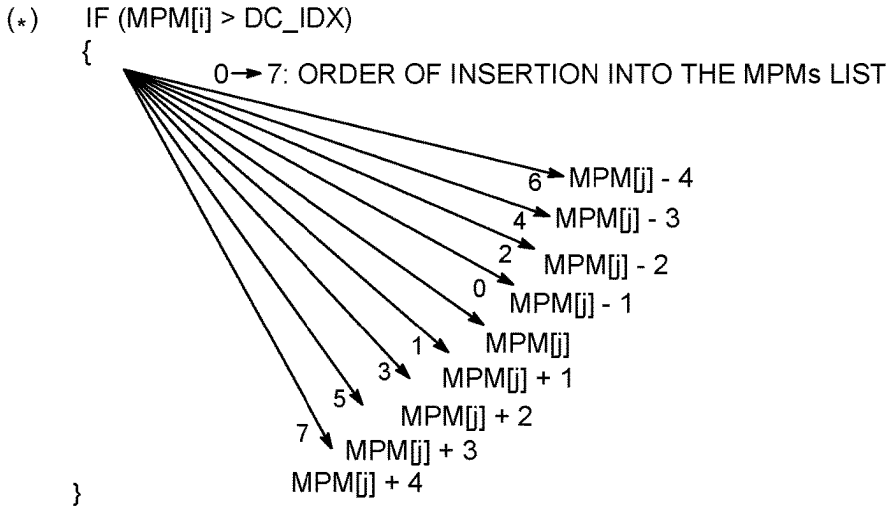

(*) IF (MPM[i] > DC_IDX)
{
0→7: ORDER OF INSERTION INTO THE MPMs LIST
6 MPM[j] - 4
4 MPM[j] - 3
2 MPM[j] - 2
0 MPM[j] - 1
1 MPM[j]
3 MPM[j] + 1
5 MPM[j] + 2
7 MPM[j] + 3
MPM[j] + 4
}

FIG. 6

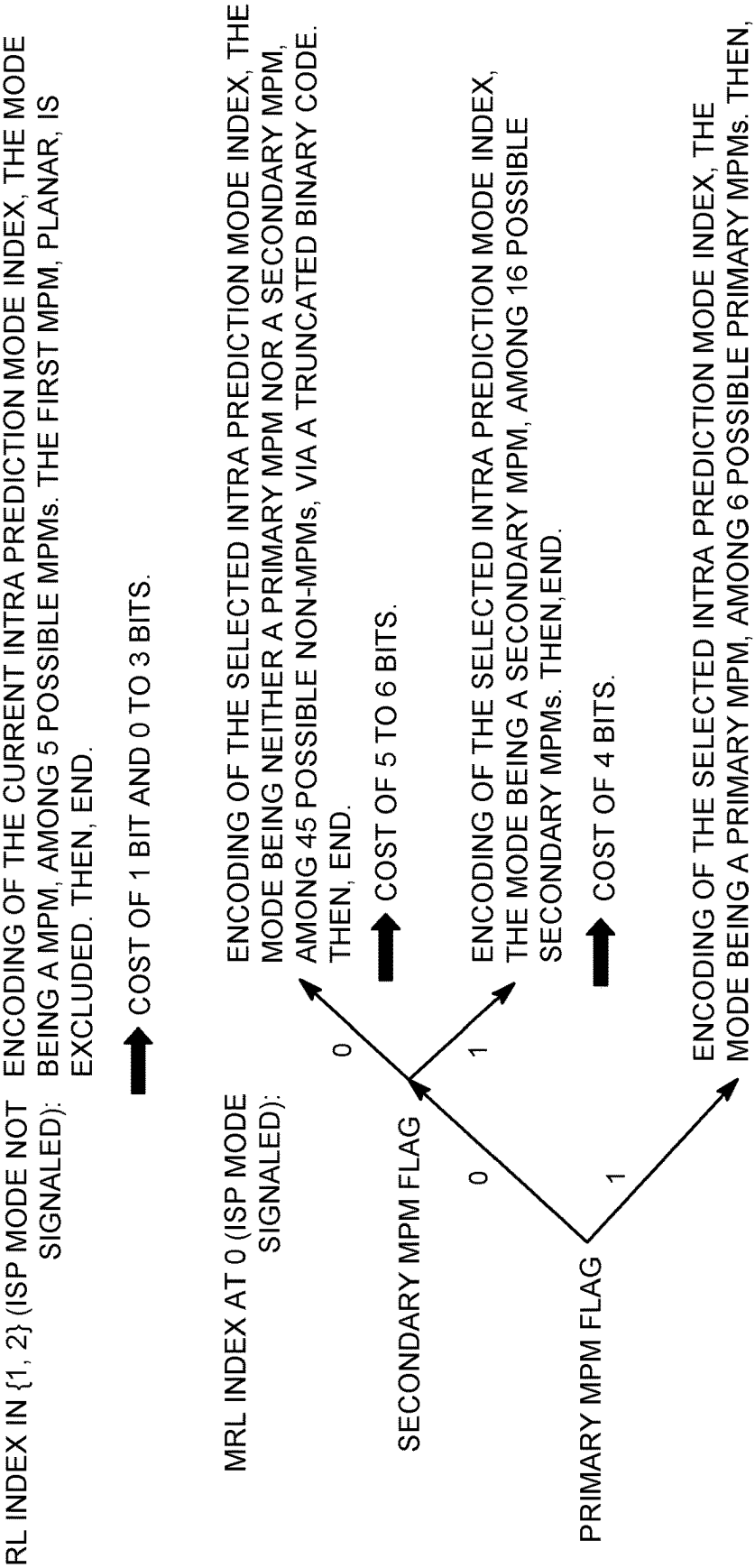

MRL INDEX IN {1, 2} (ISP MODE NOT SIGNALED):
ENCODING OF THE CURRENT INTRA PREDICTION MODE INDEX, THE MODE BEING A MPM, AMONG 5 POSSIBLE MPMs. THE FIRST MPM, PLANAR, IS EXCLUDED. THEN, END.
COST OF 1 BIT AND 0 TO 3 BITS.
MRL INDEX AT 0 (ISP MODE SIGNALED):
PRIMARY MPM FLAG
0
1
SECONDARY MPM FLAG
0
1
ENCODING OF THE SELECTED INTRA PREDICTION MODE INDEX, THE MODE BEING NEITHER A PRIMARY MPM NOR A SECONDARY MPM, AMONG 45 POSSIBLE NON-MPMs, VIA A TRUNCATED BINARY CODE. THEN, END.
COST OF 5 TO 6 BITS.
ENCODING OF THE SELECTED INTRA PREDICTION MODE INDEX, THE MODE BEING A SECONDARY MPM, AMONG 16 POSSIBLE SECONDARY MPMs. THEN,END.
COST OF 4 BITS.
ENCODING OF THE SELECTED INTRA PREDICTION MODE INDEX, THE MODE BEING A PRIMARY MPM, AMONG 6 POSSIBLE PRIMARY MPMs. THEN, END.
COST OF 1 BIT, EVENTUALLY ANOTHER BIT, AND 0 TO 3 BITS

FIG. 7

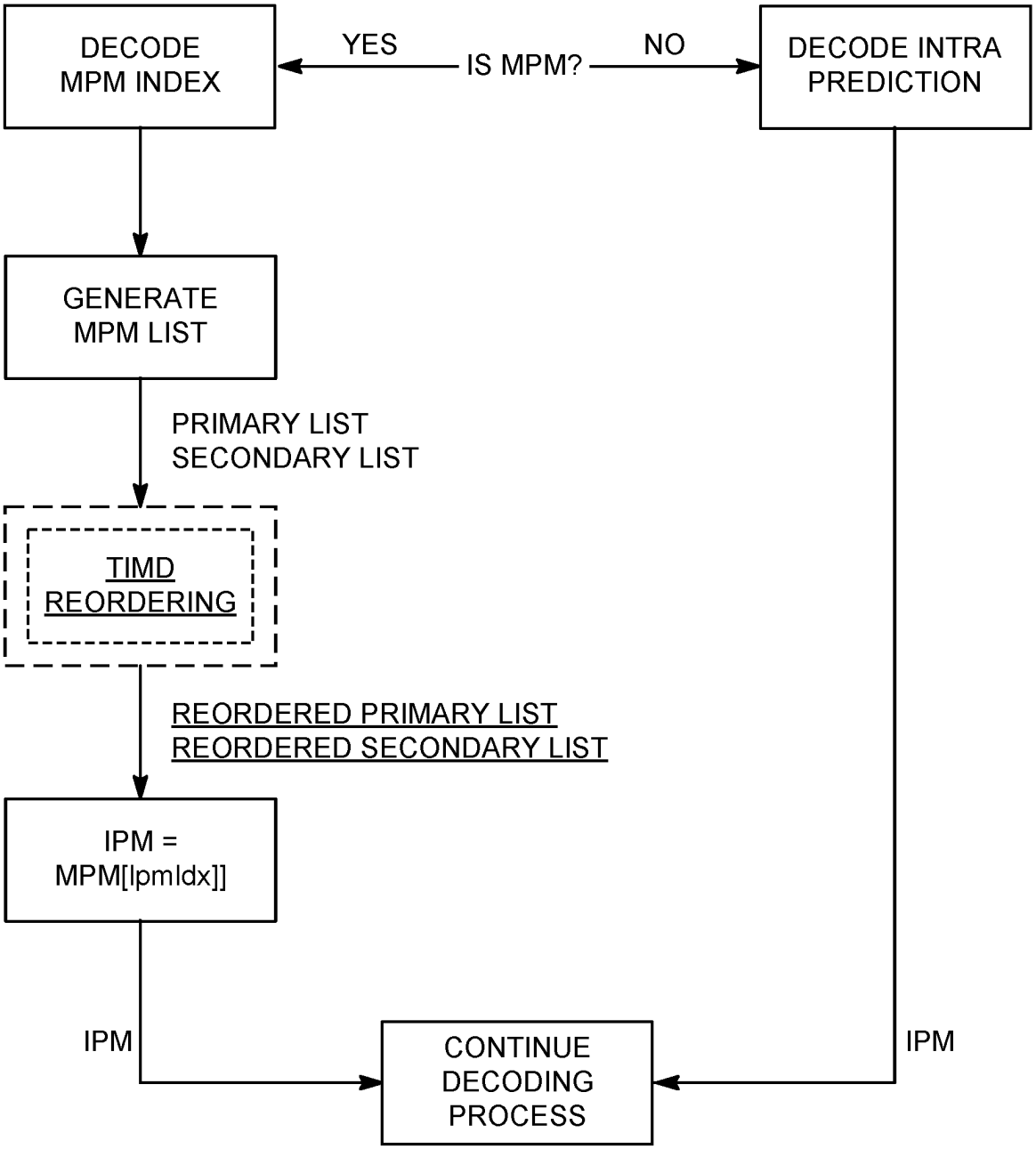

DECODE MPM INDEX
YES
IS MPM?
NO
DECODE INTRA PREDICTION
GENERATE MPM LIST
PRIMARY LIST
SECONDARY LIST
TIMD REORDERING
REORDERED PRIMARY LIST
REORDERED SECONDARY LIST
IPM = MPM[lpmIdx]]
IPM
CONTINUE DECODING PROCESS
IPM

FIG. 8

TEMPLATE BASED MOST PROBABLE MODE LIST REORDERING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of European Patent Application 22305509.6, filed Apr. 8, 2022, the disclosure of which is incorporated herein by reference in its entirety.

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 herein for the field of video compression. Examples herein aim at improving compression efficiency compared to existing video compression systems.

[0004] In examples, a video decoder may generate a most probable mode (MPM) list for a current block. The decoder may reorder the MPM based on a reordering process for each mode of the MPM list. The decoder may perform prediction for the current block based on the reordered MPM list. In examples, the reordering process may be a template-based mode derivation (TIMD) reordering process. In examples, the TIMD reordering process may compute a sum of absolute transform difference (SATD) distance for each mode of the MPM list. The SATD distance for each mode may be computed between a template sample and a prediction of the template sample. The MPM list may be reordered in order of modes with the lowest computed SATD distance to modes with the highest computed SATD distance. The MPM list may include at least one of a primary MPM list or a secondary MPM list. In examples, the reordering of the MPM list may be restricted to keeping a planar mode as a first mode. In examples, the reordering process may be a decoder-side intra mode derivation (DIMD) reordering process. The DIMD reordering process may compute a histogram of scores associated with intra predictions modes in the MPM list. The DIMD may reorder the intra prediction modes based on the computed scores associated with the intra predictions modes.

[0005] In examples, a video encoder may generate a most probable mode (MPM) list for a current block. The encoder may reorder the MPM based on a reordering process for each mode of the MPM list. The encoder may encode the current block based on the reordered MPM list. In examples, the reordering process may be a template-based mode derivation (TIMD) reordering process. In examples, the TIMD reordering process may compute a sum of absolute transform difference (SATD) distance for each mode of the MPM list. The SATD distance for each mode may be computed between a template sample and a prediction of the template sample. The MPM list may be reordered in order of modes with the lowest computed SATD distance to modes with the highest computed SATD distance. The MPM list may include at least one of a primary MPM list or a secondary MPM list. In examples, the reordering of the MPM list may be restricted to keeping a planar mode as a first mode. In examples, the reordering process may be a decoder-side intra mode derivation (DIMD) reordering process. The DIMD reordering process may compute a histogram of scores associated with intra predictions modes in the MPM list. The DIMD may reorder the intra prediction modes based on the computed scores associated with the intra predictions modes.

[0006] These examples may be performed by a video processing device with a processor. The device may be an encoder or a decoder. These examples may be performed by a computer program product which is stored on a non-transitory computer readable medium and includes program code instructions. These examples may be performed by a computer program comprising program code instructions. These examples may be performed by a bitstream comprising information representative of the template matching prediction mode.

[0007] Systems, methods, and instrumentalities described herein may involve a decoder. In some examples, the systems, methods, and instrumentalities described herein may involve an encoder. In some examples, the systems, methods, and instrumentalities described herein may involve a signal (e.g., from an encoder and/or received by a decoder). A computer-readable medium may include instructions for causing one or more processors to perform methods described herein. A computer program product may include instructions which, when the program is executed by one or more processors, may cause the one or more processors to carry out the methods described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1**A is a system diagram illustrating an example communications system in which one or more disclosed embodiments may be implemented.

[0009] FIG. **1**B is a system diagram illustrating an example wireless transmit/receive unit (WTRU) that may be used within the communications system illustrated in FIG. **1**A according to an embodiment.

[0010] FIG. **1**C 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. **1**A according to an embodiment.

[0011] FIG. **1**D 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. **1**A according to an embodiment.

[0012] FIG. **2** illustrates an example video encoder.

[0013] FIG. **3** illustrates an example video decoder.

[0014] FIG. **4** illustrates an example of a a system in which various aspects and examples may be implemented.

[0015] FIG. **5** illustrates an example of prediction modes (e.g., intra prediction modes).

[0016] FIG. **6** illustrates an example of a derivation of a most probable mode (MPM) list (e.g., a generic MPM list) for a current luminance Coding Block (CB) belonging to an intra slice.

[0017] FIG. **7** illustrates an example of signaling (e.g., MPM list-based signaling) of the index of the prediction mode (e.g., intra prediction mode) to predict the current luminance CB, if the selected prediction mode (e.g., intra prediction mode) is none of the decoder-side intra mode derivation (DIMD), matrix-based intra prediction (MIP), or template-based mode derivation (TIMD), after signaling the

Multiple Reference Line (MRL) index and signaling the Intra Sub-Partition (ISP) mode if needed.

[0018] FIG. **8** illustrates an example framework (e.g., general framework) of MPM reordering using TIMD.

DETAILED DESCRIPTION

[0019] A more detailed understanding may be had from the following description, given by way of example in conjunction with the accompanying drawings.

[0020] FIG. **1**A 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.

[0021] As shown in FIG. **1**A, the communications system **100** may include wireless transmit/receive units (WTRUs) **102***a*, **102***b*, **102***c*, **102***d*, 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 **102***a*, **102***b*, **102***c*, **102***d* may be any type of device configured to operate and/or communicate in a wireless environment. By way of example, the WTRUs **102***a*, **102***b*, **102***c*, **102***d*, 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 **102***a*, **102***b*, **102***c* and **102***d* may be interchangeably referred to as a UE.

[0022] The communications systems **100** may also include a base station **114***a* and/or a base station **114***b*. Each of the base stations **114***a*, **114***b* may be any type of device configured to wirelessly interface with at least one of the WTRUs **102***a*, **102***b*, **102***c*, **102***d* 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 **114***a*, **114***b* 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 **114***a*, **114***b* are each depicted as a single element, it will be appreciated that the base stations **114***a*, **114***b* may include any number of interconnected base stations and/or network elements.

[0023] The base station **114***a* 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 **114***a* and/or the base station **114***b* 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 **114***a* may be divided into three sectors. Thus, in one embodiment, the base station **114***a* may include three transceivers, i.e., one for each sector of the cell. In an embodiment, the base station **114***a* 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.

[0024] The base stations **114***a*, **114***b* may communicate with one or more of the WTRUs **102***a*, **102***b*, **102***c*, **102***d* 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).

[0025] 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 **114***a* in the RAN **104/113** and the WTRUs **102***a*, **102***b*, **102***c* 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).

[0026] In an embodiment, the base station **114***a* and the WTRUs **102***a*, **102***b*, **102***c* 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).

[0027] In an embodiment, the base station **114***a* and the WTRUs **102***a*, **102***b*, **102***c* may implement a radio technology such as NR Radio Access, which may establish the air interface **116** using New Radio (NR).

[0028] In an embodiment, the base station **114***a* and the WTRUs **102***a*, **102***b*, **102***c* may implement multiple radio access technologies. For example, the base station **114***a* and the WTRUs **102***a*, **102***b*, **102***c* may implement LTE radio access and NR radio access together, for instance using dual connectivity (DC) principles. Thus, the air interface utilized

by WTRUs **102***a*, **102***b*, **102***c* 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).

[0029] In other embodiments, the base station **114***a* and the WTRUs **102***a*, **102***b*, **102***c* 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 1×, 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.

[0030] The base station **114***b* in FIG. **1**A 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 **114***b* and the WTRUs **102***c*, **102***d* may implement a radio technology such as IEEE 802.11 to establish a wireless local area network (WLAN). In an embodiment, the base station **114***b* and the WTRUs **102***c*, **102***d* 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 **114***b* and the WTRUs **102***c*, **102***d* 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. **1**A, the base station **114***b* may have a direct connection to the Internet **110**. Thus, the base station **114***b* may not be required to access the Internet **110** via the CN **106/115**.

[0031] 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 **102***a*, **102***b*, **102***c*, **102***d*. 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. **1**A, 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.

[0032] The CN **106/115** may also serve as a gateway for the WTRUs **102***a*, **102***b*, **102***c*, **102***d* 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.

[0033] Some or all of the WTRUs **102***a*, **102***b*, **102***c*, **102***d* in the communications system **100** may include multi-mode capabilities (e.g., the WTRUs **102***a*, **102***b*, **102***c*, **102***d* may include multiple transceivers for communicating with different wireless networks over different wireless links). For example, the WTRU **102***c* shown in FIG. **1**A may be configured to communicate with the base station **114***a*, which may employ a cellular-based radio technology, and with the base station **114***b*, which may employ an IEEE 802 radio technology.

[0034] FIG. **1**B is a system diagram illustrating an example WTRU **102**. As shown in FIG. **1**B, 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.

[0035] 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. As suggested above, the processor **118** may include a plurality of processors. 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. **1**B 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.

[0036] The transmit/receive element **122** may be configured to transmit signals to, or receive signals from, a base station (e.g., the base station **114***a*) 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.

[0037] Although the transmit/receive element **122** is depicted in FIG. **1**B 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**.

[0038] 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.

[0039] 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).

[0040] 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.

[0041] 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 **114***a*, **114***b*) 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.

[0042] 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.

[0043] 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 WRTU **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)).

[0044] FIG. **1**C 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 **102***a*, **102***b*, **102***c* over the air interface **116**. The RAN **104** may also be in communication with the CN **106**.

[0045] The RAN **104** may include eNode-Bs **160***a*, **160***b*, **160***c*, 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 **160***a*, **160***b*, **160***c* may each include one or more transceivers for communicating with the WTRUs **102***a*, **102***b*, **102***c* over the air interface **116**. In one embodiment, the eNode-Bs **160***a*, **160***b*, **160***c* may implement MIMO technology. Thus, the eNode-B **160***a*, for example, may use multiple antennas to transmit wireless signals to, and/or receive wireless signals from, the WTRU **102***a*.

[0046] Each of the eNode-Bs **160***a*, **160***b*, **160***c* 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. **1**C, the eNode-Bs **160***a*, **160***b*, **160***c* may communicate with one another over an X2 interface.

[0047] The CN **106** shown in FIG. **1**C 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.

[0048] The MME **162** may be connected to each of the eNode-Bs **162***a*, **162***b*, **162***c* 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 **102***a*, **102***b*, **102***c*, bearer activation/deactivation, selecting a particular serving gateway during an initial attach of the WTRUs **102***a*, **102***b*, **102***c*, 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.

[0049] The SGW **164** may be connected to each of the eNode Bs **160***a*, **160***b*, **160***c* in the RAN **104** via the S1 interface. The SGW **164** may generally route and forward user data packets to/from the WTRUs **102***a*, **102***b*, **102***c*. 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 **102***a*, **102***b*, **102***c*, managing and storing contexts of the WTRUs **102***a*, **102***b*, **102***c*, and the like.

[0050] The SGW **164** may be connected to the PGW **166**, which may provide the WTRUs **102***a*, **102***b*, **102***c* with access to packet-switched networks, such as the Internet **110**, to facilitate communications between the WTRUs **102***a*, **102***b*, **102***c* and IP-enabled devices.

[0051] The CN **106** may facilitate communications with other networks. For example, the CN **106** may provide the WTRUs **102***a*, **102***b*, **102***c* with access to circuit-switched networks, such as the PSTN **108**, to facilitate communications between the WTRUs **102***a*, **102***b*, **102***c* 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 **102***a*, **102***b*, **102***c* 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.

[0052] Although the WTRU is described in FIGS. **1**A-**1**D 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.

[0053] In representative embodiments, the other network **112** may be a WLAN.

[0054] 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.

[0055] When using the 802.11ac infrastructure mode of operation or a similar mode of operations, the AP may transmit a beacon on a fixed channel, such as a primary channel. The primary channel may be a fixed width (e.g., 20 MHz wide bandwidth) or a dynamically set width via signaling. The primary channel may be the operating channel of the BSS and may be used by the STAs to establish a connection with the AP. In certain representative embodiments, Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) may be implemented, for example in in 802.11 systems. For CSMA/CA, the STAs (e.g., every STA), including the AP, may sense the primary channel. If the primary channel is sensed/detected and/or determined to be busy by a particular STA, the particular STA may back off. One STA (e.g., only one station) may transmit at any given time in a given BSS.

[0056] 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.

[0057] Very High Throughput (VHT) STAs may support 20 MHz, 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).

[0058] 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).

[0059] 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.

[0060] 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.

[0061] FIG. **1**D 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 **102***a*, **102***b*, **102***c* over the air interface **116**. The RAN **113** may also be in communication with the CN **115**.

[0062] The RAN **113** may include gNBs **180***a*, **180***b*, **180***c*, though it will be appreciated that the RAN **113** may include any number of gNBs while remaining consistent with an embodiment. The gNBs **180***a*, **180***b*, **180***c* may each include one or more transceivers for communicating with the WTRUs **102***a*, **102***b*, **102***c* over the air interface **116**. In one embodiment, the gNBs **180***a*, **180***b*, **180***c* may implement MIMO technology. For example, gNBs **180***a*, **108***b* may utilize beamforming to transmit signals to and/or receive signals from the gNBs **180***a*, **180***b*, **180***c*. Thus, the gNB **180***a*, for example, may use multiple antennas to transmit wireless signals to, and/or receive wireless signals from, the WTRU **102***a*. In an embodiment, the gNBs **180***a*, **180***b*, **180***c* may implement carrier aggregation technology. For example, the gNB **180***a* may transmit multiple component carriers to the WTRU **102***a* (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 **180***a*, **180***b*, **180***c* may implement Coordinated Multi-Point (CoMP) technology. For example, WTRU **102***a* may receive coordinated transmissions from gNB **180***a* and gNB **180***b* (and/or gNB **180***c*).

[0063] The WTRUs **102***a*, **102***b*, **102***c* may communicate with gNBs **180***a*, **180***b*, **180***c* 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 **102***a*, **102***b*, **102***c* may communicate with gNBs **180***a*, **180***b*, **180***c* 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).

[0064] The gNBs **180***a*, **180***b*, **180***c* may be configured to communicate with the WTRUs **102***a*, **102***b*, **102***c* in a standalone configuration and/or a non-standalone configuration. In the standalone configuration, WTRUs **102***a*, **102***b*, **102***c* may communicate with gNBs **180***a*, **180***b*, **180***c* without also accessing other RANs (e.g., such as eNode-Bs **160***a*, **160***b*, **160***c*). In the standalone configuration, WTRUs **102***a*, **102***b*, **102***c* may utilize one or more of gNBs **180***a*, **180***b*, **180***c* as a mobility anchor point. In the standalone configuration, WTRUs **102***a*, **102***b*, **102***c* may communicate with gNBs **180***a*, **180***b*, **180***c* using signals in an unlicensed band. In a non-standalone configuration WTRUs **102***a*, **102***b*, **102***c* may communicate with/connect to gNBs **180***a*, **180***b*, **180***c* while also communicating with/connecting to another RAN such as eNode-Bs **160***a*, **160***b*, **160***c*. For example, WTRUs **102***a*, **102***b*, **102***c* may implement DC principles to communicate with one or more gNBs **180***a*, **180***b*, **180***c* and one or more eNode-Bs **160***a*, **160***b*, **160***c* substantially simultaneously. In the non-standalone configuration, eNode-Bs **160***a*, **160***b*, **160***c* may serve as a mobility anchor for WTRUs **102***a*, **102***b*, **102***c* and gNBs **180***a*, **180***b*, **180***c* may provide additional coverage and/or throughput for servicing WTRUs **102***a*, **102***b*, **102***c*.

[0065] Each of the gNBs **180***a*, **180***b*, **180***c* 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) **184***a*, **184***b*, routing of control plane information towards Access and Mobility Management Function (AMF) **182***a*, **182***b* and the like. As shown in FIG. **1**D, the gNBs **180***a*, **180***b*, **180***c* may communicate with one another over an Xn interface.

[0066] The CN **115** shown in FIG. **1**D may include at least one AMF **182***a*, **182***b*, at least one UPF **184***a*,**184***b*, at least one Session Management Function (SMF) **183***a*, **183***b*, and possibly a Data Network (DN) **185***a*, **185***b*. 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.

[0067] The AMF **182***a*, **182***b* may be connected to one or more of the gNBs **180***a*, **180***b*, **180***c* in the RAN **113** via an N2 interface and may serve as a control node. For example, the AMF **182***a*, **182***b* may be responsible for authenticating users of the WTRUs **102***a*, **102***b*, **102***c*, support for network slicing (e.g., handling of different PDU sessions with different requirements), selecting a particular SMF **183***a*, **183***b*, management of the registration area, termination of NAS signaling, mobility management, and the like. Network slicing may be used by the AMF **182***a*, **182***b* in order to customize CN support for WTRUs **102***a*, **102***b*, **102***c* based on the types of services being utilized WTRUs **102***a*, **102***b*, **102***c*. 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.

[0068] The SMF **183***a*, **183***b* may be connected to an AMF **182***a*, **182***b* in the CN **115** via an N11 interface. The SMF **183***a*, **183***b* may also be connected to a UPF **184***a*, **184***b* in the CN **115** via an N4 interface. The SMF **183***a*, **183***b* may select and control the UPF **184***a*, **184***b* and configure the routing of traffic through the UPF **184***a*, **184***b*. The SMF **183***a*, **183***b* 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.

[0069] The UPF **184***a*, **184***b* may be connected to one or more of the gNBs **180***a*, **180***b*, **180***c* in the RAN **113** via an N3 interface, which may provide the WTRUs **102***a*, **102***b*, **102***c* with access to packet-switched networks, such as the Internet **110**, to facilitate communications between the WTRUs **102***a*, **102***b*, **102***c* and IP-enabled devices. The UPF **184**, **184***b* 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.

[0070] 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 **102***a*, **102***b*, **102***c* 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 **102***a*, **102***b*, **102***c* may be connected to a local Data Network (DN) **185***a*, **185***b* through the UPF **184***a*, **184***b* via the N3 interface to the UPF **184***a*, **184***b* and an N6 interface between the UPF **184***a*, **184***b* and the DN **185***a*, **185***b*.

[0071] In view of FIGS. **1A-1D**, and the corresponding description of FIGS. **1A-1D**, one or more, or all, of the functions described herein with regard to one or more of: WTRU **102***a-d*, Base Station **114***a-b*, eNode-B **160***a-c*, MME **162**, SGW **164**, PGW **166**, gNB **180***a-c*, AMF **182***a-b*, UPF **184***a-b*, SMF **183***a-b*, DN **185***a-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.

[0072] 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.

[0073] 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.

[0074] 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.

[0075] The aspects described and contemplated in this application may be implemented in many different forms. FIGS. **5-8** described herein may provide some examples, but other examples are contemplated. The discussion of FIGS. **5-8** 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.

[0076] 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.

[0077] 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.

[0078] 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.

[0079] Various numeric values are used in examples described the present application, such as bits, bit depth, etc. These and other specific values are for purposes of describing examples and the aspects described are not limited to these specific values.

[0080] 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.

[0081] 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.

[0082] 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.

[0083] 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.

[0084] 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**).

[0085] 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.

[0086] 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**).

[0087] 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.

[0088] FIG. **4** 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.

[0089] 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.

[0090] 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.

[0091] 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.

[0092] 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.

[0093] 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. **4**, include composite video.

[0094] In various examples, the input devices of block **445** have associated respective input processing elements as known in the art. For example, the RF portion may be associated with elements suitable for (i) selecting a desired frequency (also referred to as selecting a signal, or band-limiting a signal to a band of frequencies), (ii) downconverting the selected signal, (iii) band-limiting again to a narrower band of frequencies to select (for example) a signal frequency band which may be referred to as a channel in certain examples, (iv) demodulating the downconverted and band-limited signal, (v) performing error correction, and/or (vi) demultiplexing to select the desired stream of data packets. The RF portion of various examples includes one or more elements to perform these functions, for example, frequency selectors, signal selectors, band-limiters, channel selectors, filters, downconverters, demodulators, error correctors, and demultiplexers. The RF portion can include a tuner that performs various of these functions, including, for example, downconverting the received signal to a lower frequency (for example, an intermediate frequency or a near-baseband frequency) or to baseband. In one set-top box example, the RF portion and its associated input processing element receives an RF signal transmitted over a wired (for example, cable) medium, and performs frequency selection by filtering, downconverting, and filtering again to a desired frequency band. Various examples rearrange the order of the above-described (and other) elements, remove some of these elements, and/or add other elements performing similar or different functions. Adding elements can include inserting elements in between existing elements, such as, for example, inserting amplifiers and an analog-to-digital converter. In various examples, the RF portion includes an antenna.

[0095] The USB and/or HDMI terminals can include respective interface processors for connecting system **400** to other electronic devices across USB and/or HDMI connections. It is to be understood that various aspects of input processing, for example, Reed-Solomon error correction, may be implemented, for example, within a separate input processing IC or within processor **410** as necessary. Similarly, aspects of USB or HDMI interface processing may be implemented within separate interface ICs or within processor **410** as necessary. The demodulated, error corrected, and demultiplexed stream is provided to various processing elements, including, for example, processor **410**, and encoder/decoder **430** operating in combination with the memory and storage elements to process the datastream as necessary for presentation on an output device.

[0096] 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.

[0097] The system **400** includes communication interface **450** that enables communication with other devices via communication channel **460**. The communication interface **450** can include, but is not limited to, a transceiver configured to transmit and to receive data over communication channel **460**. The communication interface **450** can include, but is not limited to, a modem or network card and the communication channel **460** may be implemented, for example, within a wired and/or a wireless medium.

[0098] Data is streamed, or otherwise provided, to the system **400**, in various examples, using a wireless network such as a Wi-Fi network, for example IEEE 802.11 (IEEE refers to the Institute of Electrical and Electronics Engineers). The Wi-Fi signal of these examples is received over the communications channel **460** and the communications interface **450** which are adapted for Wi-Fi communications. The communications channel **460** of these examples is typically connected to an access point or router that provides access to external networks including the Internet for allowing streaming applications and other over-the-top communications. Other examples provide streamed data to the system **400** using a set-top box that delivers the data over the HDMI connection of the input block **445**. Still other examples provide streamed data to the system **400** using the RF connection of the input block **445**. As indicated above, various examples provide data in a non-streaming manner. Additionally, various examples use wireless networks other than Wi-Fi, for example a cellular network or a Bluetooth® network.

[0099] The system **400** can provide an output signal to various output devices, including a display **475**, speakers **485**, and other peripheral devices **495**. The display **475** of various examples includes one or more of, for example, a touchscreen display, an organic light-emitting diode (OLED) display, a curved display, and/or a foldable display. The display **475** may be for a television, a tablet, a laptop,

a cell phone (mobile phone), or other device. The display **475** can also be integrated with other components (for example, as in a smart phone), or separate (for example, an external monitor for a laptop). The other peripheral devices **495** include, in various examples, one or more of a stand-alone digital video disc (or digital versatile disc) (DVD, for both terms), a disk player, a stereo system, and/or a lighting system. Various examples use one or more peripheral devices **495** that provide a function based on the output of the system **400**. For example, a disk player performs the function of playing the output of the system **400**.

[0100] In various examples, control signals are communicated between the system **400** and the display **475**, speakers **485**, or other peripheral devices **495** using signaling such as AV.Link, Consumer Electronics Control (CEC), or other communications protocols that enable device-to-device control with or without user intervention. The output devices may be communicatively coupled to system **400** via dedicated connections through respective interfaces **470**, **480**, and **490**. Alternatively, the output devices may be connected to system **400** using the communications channel **460** via the communications interface **450**. The display **475** and speakers **485** may be integrated in a single unit with the other components of system **400** in an electronic device such as, for example, a television. In various examples, the display interface **470** includes a display driver, such as, for example, a timing controller (T Con) chip.

[0101] The display **475** and speakers **485** can alternatively be separate from one or more of the other components, for example, if the RF portion of input **445** is part of a separate set-top box. In various examples in which the display **475** and speakers **485** are external components, the output signal may be provided via dedicated output connections, including, for example, HDMI ports, USB ports, or COMP outputs.

[0102] The examples may be carried out by computer software implemented by the processor **410** or by hardware, or by a combination of hardware and software. As a non-limiting example, the examples may be implemented by one or more integrated circuits. The memory **420** may be of any type appropriate to the technical environment and may be implemented using any appropriate data storage technology, such as optical memory devices, magnetic memory devices, semiconductor-based memory devices, fixed memory, and removable memory, as non-limiting examples. The processor **410** may be of any type appropriate to the technical environment, and can encompass one or more of microprocessors, general purpose computers, special purpose computers, and processors based on a multi-core architecture, as non-limiting examples.

[0103] 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, generating a most probable mode (MPM) list for a current block; reordering the MPM list based on a reordering process for each mode of the MPM list; and performing prediction for the current block based on the reordered MPM list, etc.

[0104] 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.

[0105] 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, generating a most probable mode (MPM) list for a current block; reordering the MPM list based on a reordering process for each mode of the MPM list; and encoding the current block based on the reordered MPM list, etc.

[0106] 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.

[0107] Note that syntax elements as used herein, for example, including but not limited to, MpmFlag and SecondaryMpmFlag are descriptive terms. As such, they do not preclude the use of other syntax element names.

[0108] 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.

[0109] 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.

[0110] Reference to "one example" or "an example" or "one implementation" or "an implementation", as well as other variations thereof, means that a particular feature, structure, characteristic, and so forth described in connection with the example is included in at least one example. Thus, the appearances of the phrase "in one example" or "in an example" or "in one implementation" or "in an implementation", as well any other variations, appearing in various places throughout this application are not necessarily all referring to the same example.

[0111] 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.

[0112] 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.

[0113] 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.

[0114] 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.

[0115] Also, as used herein, the word "signal" refers to, among other things, indicating something to a corresponding decoder. 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" may (e.g., may also) be used herein as a noun.

[0116] 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.

[0117] 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.

[0118] The syntax elements values may be predicted from previously coded blocks whose pixels (e.g., L-shaped pixels) surrounding the blocks match the current block template. The examples described herein may increase coding gain and/or decrease signaling of syntax elements.

[0119] These examples may be performed by a device with at least one processor. The device may be an encoder or a decoder. These examples may be performed by a computer program product which is stored on a non-transitory computer readable medium and includes program code instructions. These examples may be performed by a com-

puter program comprising program code instructions. These examples may be performed by a bitstream comprising information representative of template matching prediction mode.

[0120] Prediction (e.g., intra prediction) may be a coding tool used in video coding (e.g., hybrid video coding). For a given block (e.g., current block) to be predicted, the encoder may select the best prediction mode (e.g., intra prediction mode) in terms of rate-distortion. The encoder may select the best prediction mode (e.g., intra prediction mode) index to the decoder so that for this block (e.g., current block), the decoder may perform the same prediction. Signaling the mode index may add extra overhead and reduce the gain from intra part. Therefore, a way of coding the index of the prediction mode (e.g., intra prediction mode) selected to predict a given block may be to create a set of most probable modes (MPMs), and thus reduce the signaling overhead if the index of the selected mode belongs to that list. These examples may be used for signaling the prediction mode index (e.g., intra prediction mode index), which may be known as MPM list-based signaling. In examples, multiple MPM lists (e.g., two MPM lists) may be used instead of one. In examples herein related to MPM list-based signaling, a signaling of a mode index may be shortened to the signaling of a mode.

[0121] In examples, prediction modes (e.g., two additional intra prediction modes) may be introduced. Example prediction modes may include decoder-side intra mode derivation (DIMD) and template-based intra mode derivation (TIMD). In these modes (e.g., both modes), the reconstructed pixels surrounding the current block on the top and left directions (e.g., template pixels) may be used to derive the prediction modes (e.g., intra prediction modes). In DIMD, the template of reconstructed pixels may be analyzed to deduce the directionalities of the template, from which the directional modes (e.g., two directional modes) may be selected. The prediction signal may be generated by blending the modes (e.g., two modes) with the planar mode. In TIMD, prediction modes (e.g., intra prediction modes) may be tested on the template of reconstructed pixels. The best modes (e.g., the two best modes) may be selected (e.g., the modes which minimize the sum of absolute transform difference (SATD) between the template of reconstructed pixels and its prediction). The prediction signal may be generated by either applying the best mode or blending those modes (e.g., two modes), depending on their prediction SATDs.

[0122] In DIMD, two intra modes may be derived from the reconstructed neighbor samples. The two intra modes (e.g., predictors) may be combined with the planar mode predictor with the weights derived from gradients. The division operations in weight derivation may be performed utilizing the same lookup table (LUT) based integerization scheme used by the cross-complaint linear model (CCLM). For example, the division operation in the orientation calculation

$$\text{Orient} = G_y/G_x$$

may be computed by the following LUT-based scheme:

$$x = \text{Floor}(\text{Log2}(Gx))$$

$$normDiff = ((Gx \ll 4) \gg x) \,\&\, 15$$

$$x \mathrel{+}= (3 + (normDiff \mathrel{!}= 0) ? 1 : 0)$$

$$\text{Orient} = (Gy * (DivSigTable[normDiff] \mid 8) + (1 \ll (x - 1))) \gg x,$$

where

$$\text{DivSigTable}[16]\{0,7,6,5,5,4,4,3,3,2,2,1,1,1,1,0\}.$$

[0123] Derived intra modes may be included in the primary list of intra most probable modes (MPM), and the DIMD process may be performed before the MPM list is constructed. The primary derived intra mode of a DIMD block may be stored with a block and may be used for MPM list construction of the neighboring blocks. In examples, the MPM lists may include the modes generated from DIMD.

[0124] In TIMD, at least one of the following modes may be the modes (e.g., may be the only modes) tested on the template surrounding the current block: the prediction modes (e.g., intra prediction modes) in the MPM lists (e.g., two MPM lists); default prediction modes (e.g., several default intra prediction modes); or potentially the extended directional intra prediction modes that may be neighbors of retained prediction modes (e.g., two retained directional intra prediction modes). For the tested modes (e.g., for each tested mode), the SATD between the template of decoded pixels surrounding the current block and the prediction of the template via the mode (also called SATD distance) may be computed. This SATD distance may be used to reorder the MPM list such that the least distant modes are put first in the MPM list. This reordering process may lead to better representation of the probable modes and therefore better signaling.

[0125] FIG. **5** illustrates an example of prediction modes (e.g., intra prediction modes). Examples of prediction modes (e.g., core 67 intra prediction modes) may be provided herein. To capture the arbitrary edge directions presented in natural video, the number of modes (e.g., directional intra modes) may be extended from 33 to 65. Directional modes may be depicted as dotted arrows in FIG. **5**. These denser directional modes (e.g., directional intra prediction modes) may apply for different block sizes (e.g., all block sizes) and for different predictions (e.g., both luma and chroma intra predictions). Prediction modes (e.g., several angular intra prediction modes) may be replaced (e.g., adaptively replaced) with wide-angle intra prediction modes for the non-square blocks.

[0126] The planar and DC modes may remain unchanged (e.g., excluding the following minor modification). Intra-coded blocks (e.g., every intra-coded block) may have a square shape and the length of each of its sides may be a power of 2. Therefore, no division operations may be required to generate an intra-predictor using the DC mode. Blocks may have a rectangular shape may require the use of a division operation per block in the general case. To avoid division operations for DC prediction, the longer side (e.g., only the longer side) may be used to compute the average for non-square blocks.

[0127] Examples of the core structure of the prediction modes (e.g., 67 intra prediction modes) may be provided

herein. This core structure may be refined in at least one of the following ways: the four-tap interpolation for a directional intra prediction mode may become a six-tap interpolation; or position dependent intra prediction combination (PDPC) may be supplemented with a gradient PDPC.

[0128] FIG. **6** illustrates an example of a derivation of a MPM list (e.g., a generic MPM list) for a current luminance coding block (CB) belonging to an intra slice. Examples of MPM list-based signaling may be provided herein. If the prediction mode (e.g., intra prediction mode) selected to predict the current luminance CB is neither a matrix-based intra prediction (MIP) mode, nor DIMD, nor TIMD, (e.g., it is one of the 67 intra prediction modes), its index may be signaled using the MPM list of this CB. The MPM list (e.g., generic MPM list) may be decomposed into a list of 6 primary MPMs and a list of 22 secondary MPMs (e.g., as shown in FIG. 6). The generic MPM list may be built by adding (e.g., sequentially adding) candidate prediction mode indices, from the one most likely of being the selected prediction mode for predicting the current luminance CB to the least likely one. FIG. **6** shows, from left to right, the sequential addition of the candidate intra prediction mode indices in the case where the current luminance CB belongs to an intra slice. No redundancy may exist in the generic list of MPMs, meaning that it may not include identical (e.g., two identical) prediction mode (e.g., intra prediction mode) indices. FIG. **6** illustrates an example where each candidate prediction mode index (e.g., intra prediction mode index) may be different from one another. In examples (e.g., in the generic case), the slots of indices 0 to i−1 included in the generic list of MPMs may have already been filled. If the current candidate prediction mode index already exists in the current generic list of MPMs, this candidate may be skipped and the next candidate prediction mode may be inserted at the slot of index i if it does not exist in the generic list of MPMs. The current prediction mode index may be (e.g., may be otherwise) inserted at the slot of index i and the next candidate prediction mode may be inserted at the slot of index i+1 if it does not exist in the generic list of MPMs.

[0129] FIG. **7** illustrates an example of signaling (e.g., MPM list-based signaling) of the index of the prediction mode (e.g., intra prediction mode) to predict the current luminance CB, if the selected prediction mode (e.g., intra prediction mode) is neither DIMD nor MIP nor TIMD, after signaling the multiple reference line (MRL) index and signaling the intra sub-partition (ISP) mode if needed. FIG. **7** illustrates that the MPM list-based signaling may implement a hierarchical entropy coding of the index of the intra prediction mode selected to predict the current luminance CB. Block differential pulse code modulation (BDPCM), template matching prediction (TMP), intra block copy (IBC), and Palette may be deactivated (e.g., in examples), as these tools may be optionally used for specific video sequences/configurations exclusively.

[0130] Examples of fusion for template-based intra mode derivation (TIMD) are provided herein. For the current luminance CB, for prediction modes (e.g., for each intra prediction mode) in its MPM list supplemented with default modes, the SATD between the prediction of the template of this CB via this mode and the reconstructed samples of the template may be calculated. The prediction modes (e.g., two intra prediction modes) with the minimum SATDs may be selected as the TIMD modes. For TIMD, the set of directional intra prediction mode may be extended from 65 to 129 by inserting a direction between each solid arrow and its neighboring dotted arrow in FIG. **5**. This means that the set of possible intra prediction modes derived via TIMD may gather 131 modes. If retaining (e.g., after retaining) prediction modes (e.g., two intra prediction modes) from the first pass of tests involving the MPM list supplemented with default modes, for each of these modes (e.g., two modes), if this mode is neither planar nor DC, TIMD may test (e.g., also test), in terms of prediction SATD, its closest (e.g., two closest) extended directional intra prediction modes. The TIMD modes (e.g., two TIMD modes) resulting from the passes (e.g., two passes) of tests may be fused with the weights if applying (e.g., after applying) PDPC. Such weighted intra prediction may be used to code the current luminance CB. PDPC may be included in the derivation of the TIMD modes.

[0131] The costs of the selected modes (e.g., two selected modes) may be compared with a threshold. In the test, the cost factor of 2 is applied as follows:

$$costMode2 < 2 * costMode1$$

[0132] If this condition is true, the fusion is applied, otherwise the only model is used.

[0133] Weights of the modes are computed from their SATD costs as follows:

$$\text{weight1} = costMode2/(costMode1 + costMode2)$$

$$\text{weight2} = 1 - \text{weight1}$$

[0134] The division operations may be conducted using the same lookup table (LUT) based integerization scheme used by the Cross-Component Linear Model (CCLM).

[0135] Examples of reordering at least one of a primary MPM list or a secondary MPM list are provided herein. In examples, the reordering may be applied to (e.g., only applied to) the primary MPMs. This is because the secondary MPMs may be bypass coded, and therefore the reordering may not have any impact on the coding performance. The reordering may be restricted to keeping the planar mode as the first mode inside MPMs, and the reordering starts after that. This is because the planar mode may be a powerful mode that is frequently used for the intra coded blocks. The last bit in MPM (B3 in the coding table) may be (e.g., may also be) syntax coded. This is because the modes may be well sorted, and syntax coding can provide better coding in this case.

[0136] Examples of reordering the secondary MPM are provided herein. For the secondary MPMs, its 16 modes may be bypass coded. Therefore, proper binarization may be needed. The same binarization for the secondary MPM may be used as in the primary MPMs. Use one bit for the first mode, 2 for the second, and so on. The following may be done:

```
MpmIdx = 0
For i=0:length(SecondayMpmList)-1
  MpmIdx = MpmIdx + decodeBin( )
  If (Bin == 0)
    Break
  End
End
```

[0137] In these examples, the higher the index, the higher the bits that may be required to signal that mode. For example, 16 bits may be required to signal the last index. The first three bits may be used for this type of signaling, and rest of the bits may be bypass coded the rest. The following may be done:

```
MpmIdx = 0
For i=0:2
  MpmIdx = MpmIdx + decodeBin( )
  If (Bin == 0)
    Break
  End
End
If (MpmIdx > 2)
  MpmIdx = MpmIdx + readTruncatedBinCode( )
End
```

[0138] FIG. **8** illustrates an example framework (e.g., general framework) of MPM reordering using TIMD. The dashed rectangle may represent an added process to reorder the MPM list. A MPM list may be generated for a current block. The MPM list may be reordered based on a reordering process for each mode of the MPM list. The MPM list may be reordered according to the distances computed by a TIMD reordering process. In examples, the TIMD reordering process may test MPMs on the available template of decoded samples and measure the distance for each mode of the MPM list. In examples, the distance for each mode of the MPM list may be computed by using a SATD/SAD of each mode. Prediction may be performed by a video decoding device for the current block based on the reordered MPM list. A video encoding device may encode the current block based on the reordered MPM list.

[0139] The TIMD reordering process may test possible MPMs (e.g., all possible MPMs) on the template samples surrounding the current block. For the modes (e.g., each mode), the SATD distance (e.g., the SATD between the template and a prediction of the template via this mode) is measured, and the prediction modes (e.g., two intra prediction modes) with the minimum distance may be selected for the fusion process. The MPM list may be reordered in order of modes with the lowest computed SATD distance to modes with the highest computed SATD distance. The same process may be used to reorder the MPM lists. The algorithmic description is provided in Table 1.

TABLE 1

algorithmic description of the reordering of the MPMs list, denoted "MmpList", into "NewMpmList" via TIMD.

```
MPM reordering(MmpList[ ]){
  For i=0:length(MpmList)-1
    DistList[i] = Compute_satd(MpmList[i])
  End
  SortIdxList = getSortingIndex(DistList)
  For i=0:length(MpmList)-1
    NewMpmList[i] = MpmList[SortIdxList[i]]
  End
  Return NewMpmList
end
```

TABLE 1-continued

algorithmic description of the reordering of the MPMs list, denoted "MmpList", into "NewMpmList" via TIMD.

[0140] In Table 1, if the chosen distance measure is a conventional distance measure in mathematics or video compression (e.g., such as SAD, SATD, sum of squared differences (SSD)), "getSortingIndex" may sort the indices according to their respective distances in "DisList" in ascending order. For an intra prediction mode tested via TIMD, a distance (e.g., relatively small conventional distance) between the template of the current block and the prediction of the template via this mode may indicate that this tested mode is relatively likely to be selected to predict the current block. If the chosen distance is the inverse of a conventional distance measure or the opposite of a conventional distance measure in mathematics or video compression, "getSortingIndex" may sort the indices according to their respective distances in "DisList" in descending order.

[0141] In examples, a DIMD flag may be set to indicate intra prediction mode derivation is to be performed by the decoder. In case of DIMD, a histogram of gradients or directions may be generated, for example, based on a template associated with the current block. The histogram may be generated based on a score associated with each of the gradients or directions. Each of the calculated gradients or directions may be associated with an intra prediction mode and stored in an MPM list. The MPM list may then be reordered using the histogram values or scores associated with each of the gradients or directions or each of the intra prediction modes.

[0142] Examples of binarization of modes (e.g., intra modes) may be provided. On the decoder side, for a given luminance CB predicted in intra, if the DIMD flag is 0 (e.g., if the DIMD is not used), the MIP flag may be 0 (e.g., the selected intra prediction mode may not be MIP), the TIMD flag may be 0 (e.g., TIMD may not be used), and the MRL index may be 0 (e.g., the MRL may not be used). The MPM list-based signaling of the index of the prediction mode (e.g., intra prediction mode) selected to predict this luminance CB may defined as in Table 2. BDPCM, template matching prediction (TMP), intra block copy (IBC), and palette may be deactivated as these tools are optionally used for specific video sequences/configurations exclusively.

TABLE 2

MPM list-based signaling of the index of the intra prediction mode selected to predict the current luminance CB when the DIMD flag is 0, the MIP flag is 0, the TIMD flag is 0, and the MRL index is 0.

```
MpmFlag = decodeBin(ctx1)
If (MpmFlag)
  IsPlanar = decodeBin(ctx2)
  If (IsPlanar == 0)
    MpmIdx = 1 + decodeBin(ctx3)
  Else
    IntraMode = MODE_PLANAR
```

TABLE 2-continued

MPM list-based signaling of the index of the intra prediction mode selected to predict the current luminance CB when the DIMD flag is 0, the MIP flag is 0, the TIMD flag is 0, and the MRL index is 0.

```
    If (MpmIdx > 1)
      MpmIdx = MpmIdx + decodeBinEP( )
    End
    If (MpmIdx > 2)
      MpmIdx = MpmIdx + decodeBinEP( )
    End
    If (MpmIdx > 3)
      MpmIdx = MpmIdx + decodeBinEP( )
    End
    IntraMode = MPM[MpmIdx]
  Else // not primary MPM
    SecondaryMpmFlag = decodeBin(ctx4)
    If (SecondaryMpmFlag)
      MpmIdx = decodeBinsEP(4)
      IntraMode = SecondaryMPM[MpmIdx]
    Else
      IntraMode = readTruncatedBinCode( )
    End
  End
```

[0143] decodeBin(Ctx_i) may be context-based decoding of one binary value using the context Ctx_i. decodeBinEP( ) may be bypass decoding of one binary value. decodeBinsEP(n) may be bypass decoding of n binary values. readTruncatedBinCode may be the default decoding process of non-MPM intra modes.

[0144] The signaling table is provided (B1* and B2* are syntax coded, and the rest are bypass coded) in Table 3.

TABLE 3

signaling table for the intra prediction mode selected to predict the current luminance CB when the DIMD flag is 0, the MIP flag is 0, the TIMD flag is 0, and the MRL index is 0.

IntraMode	MpmFlag	SecondaryMpmFlag	B1*	B2*	B3	B4	B5	B6	B7	B8
PLANAR	1	X	0	X	X	X	X	X	X	X
MPM[1]	1	X	1	0	X	X	X	X	X	X
MPM[2]	1	X	1	1	0	X	X	X	X	X
MPM[3]	1	X	1	1	0	X	X	X	X	X
MPM[4]	1	X	1	1	1	0	X	X	X	X
MPM[5]	1	X	1	1	1	1	X	X	X	X
SMPM[0]	0	1	X	X	X	X	0	0	0	0
SMPM[1]	0	1	X	X	X	X	0	0	0	1
SMPM[2]	0	1	X	X	X	X	0	0	1	0
SMPM[3]	0	1	X	X	X	X	0	0	1	1
SMPM[4]	0	1	X	X	X	X	0	1	0	0
SMPM[5]	0	1	X	X	X	X	0	1	0	1
SMPM[6]	0	1	X	X	X	X	0	1	1	0
SMPM[7]	0	1	X	X	X	X	0	1	1	1
SMPM[8]	0	1	X	X	X	X	1	0	0	0
SMPM[9]	0	1	X	X	X	X	1	0	0	1
SMPM[10]	0	1	X	X	X	X	1	0	1	0
SMPM[11]	0	1	X	X	X	X	1	0	1	1
SMPM[12]	0	1	X	X	X	X	1	1	0	0
SMPM[13]	0	1	X	X	X	X	1	1	0	1
SMPM[14]	0	1	X	X	X	X	1	1	1	0
SMPM[15]	0	1	X	X	X	X	1	1	1	1

[0145] From the signaling table, less bits may be required to signal the first most probable mode compared to the second (third, etc.) mode. That is, a single bit for signaling the first mode, and two bits for the second mode, and so on. This may provide probable modes that are sorted such that less bits for the first modes may be used. The third bit (B33) may be bypass coded. This is because it may be (e.g., equally) probable that whether the fifth or sixth MPM mode is used. If MPM is well sorted, syntax-based coding may be used, and improved coding can be achieved. Regarding the secondary MPM, they may be (e.g., they may all be) bypass coded. If the modes inside them are sorted, syntax coding may be used.

[0146] 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.

1-36. (canceled)

37. A device for video decoding, comprising:

a processor configured to:

generate a most probable mode (MPM) list for a current block, wherein the MPM list comprises a first MPM list and a second MPM list;

reorder the first MPM list based on a first reordering process to obtain the reordered first MPM list;

reorder the second MPM list based on a second reordering process to obtain the reordered second MPM list, wherein the second reordering process is different than the first reordering process; and

perform prediction for the current block based on the reordered first MPM list and the reordered second MPM list.

38. The device of claim 37, wherein the first reordering process is a template-based reordering process and the second reordering process is a decoder-side intra mode derivation (DIMD) reordering process.

39. The device of claim 38, wherein template-based process is a template-based intra mode derivation (TIMD) reordering process, and wherein the TIMD reordering process comprises computing a sum of absolute transform difference (SATD) distance for each prediction mode of the first MPM list.

40. The device of claim 38, wherein the DIMD reordering process comprises computing a histogram of scores associated with prediction modes in the second MPM list and reordering the prediction modes based on the computed histogram of scores associated with the prediction modes.

41. The device of claim 37, wherein the processor is further configured to:

set a planar mode as a first mode of the first MPM list or the second MPM list for the current block.

42. The device of claim 41, wherein the processor is further configured to:

keep the planar mode as the first mode of the first MPM list or the second MPM list, wherein the reordering of the first MPM list or the second MPM list is performed after the planar mode is kept as the first mode.

43. The device of claim 37, wherein the processor is further configured to:

receive a first portion of a first set of bits associated with prediction modes in the reordered first MPM list using syntax coding; and

receive a second portion of the first set of bits associated with the prediction modes in the reordered first MPM list and a second set of bits associated with prediction modes in the reordered second MPM list using bypass coding.

44. A method for video decoding, the method comprising:

generating a most probable mode (MPM) list for a current block, wherein the MPM list comprises a first MPM list and a second MPM list;

reordering the first MPM list based on a first reordering process to obtain the reordered first MPM list;

reordering the second MPM list based on a second reordering process to obtain the reordered second MPM list, wherein the second reordering process is different than the first reordering process; and

performing prediction for the current block based on the reordered first MPM list and the reordered second MPM list.

45. The method of claim 44, wherein the first reordering process is a template-based reordering process and the second reordering process is a decoder-side intra mode derivation (DIMD) reordering process.

46. The method of claim 45, wherein template-based process is a template-based intra mode derivation (TIMD) reordering process, and wherein the TIMD reordering process comprises computing a sum of absolute transform difference (SATD) distance for each prediction mode of the first MPM list.

47. The method of claim 45, wherein the DIMD reordering process comprises computing a histogram of scores associated with prediction modes in the second MPM list and reordering the prediction modes based on the computed histogram of scores associated with the prediction modes.

48. The method of claim 44, further comprising:

setting a planar mode as a first mode of the first MPM list or the second MPM list for the current block.

49. The method of claim 44, further comprising:

receiving a first portion of a first set of bits associated with prediction modes in the reordered first MPM list using syntax coding; and

receiving a second portion of the first set of bits associated with the prediction modes in the reordered first MPM list and a second set of bits associated with prediction modes in the reordered second MPM list using bypass coding.

50. A device for video encoding, comprising:

a processor configured to:

generate a most probable mode (MPM) list for a current block, wherein the MPM list comprises a first MPM list and a second MPM list;

reorder the first MPM list based on a first reordering process to obtain the reordered first MPM list;

reorder the second MPM list based on a second reordering process to obtain the reordered second MPM list, wherein the second reordering process is different than the first reordering process; and

encode the current block based on the reordered first MPM list and the reordered second MPM list.

51. The device of claim 50, wherein the first reordering process is a template-based reordering process and the second reordering process is a decoder-side intra mode derivation (DIMD) reordering process.

52. The device of claim 51, wherein template-based process is a template-based intra mode derivation (TIMD) reordering process, and wherein the TIMD reordering process comprises computing a sum of absolute transform difference (SATD) distance for each prediction mode of the first MPM list.

53. The device of claim 51, wherein the DIMD reordering process comprises computing a histogram of scores associated with prediction modes in the second MPM list and reordering the prediction modes based on the computed histogram of scores associated with the prediction modes.

54. The device of claim 50, wherein the processor is further configured to:

set a planar mode as a first mode of the first MPM list or the second MPM list for the current block.

55. The device of claim 54, wherein the processor is further configured to:

keep the planar mode as the first mode of the first MPM list or the second MPM list, wherein the reordering of the first MPM list or the second MPM list is performed after the planar mode is kept as the first mode.

56. The device of claim 50, wherein the processor is further configured to:

send a first portion of a first set of bits associated with prediction modes in the reordered first MPM list using syntax coding; and

send a second portion of the first set of bits associated with the prediction modes in the reordered first MPM list and a second set of bits associated with prediction modes in the reordered second MPM list using bypass coding.

* * * * *