

CODEC RATE ADAPTION FOLLOWING DYNAMIC ENB BANDWIDTH NOTIFICATION

BACKGROUND

5 [0001] Wireless mobile communication technology uses various standards and protocols to transmit data between a node (e.g., a transmission station) and a wireless device (e.g., a mobile device). Some wireless devices communicate using orthogonal frequency-division multiple access (OFDMA) in a downlink (DL) transmission and single carrier frequency division multiple access (SC-FDMA) in uplink (UL). Standards and
10 protocols that use orthogonal frequency-division multiplexing (OFDM) for signal transmission include the third generation partnership project (3GPP) long term evolution (LTE), the Institute of Electrical and Electronics Engineers (IEEE) 802.16 standard (e.g., 802.16e, 802.16m), which is commonly known to industry groups as WiMAX (Worldwide interoperability for Microwave Access), and the IEEE 802.11 standard,
15 which is commonly known to industry groups as WiFi.

[0002] In 3GPP radio access network (RAN) LTE systems (e.g., Release 13 and earlier), the node can be a combination of Evolved Universal Terrestrial Radio Access Network (E-UTRAN) Node Bs (also commonly denoted as evolved Node Bs (eNB), enhanced Node Bs, eNodeBs, or eNBs), which communicate with the wireless device,
20 known as a user equipment (UE). The downlink (DL) transmission can be a communication from the node (e.g., eNodeB) to the wireless device (e.g., UE), and the uplink (UL) transmission can be a communication from the wireless device to the node.

[0003] LTE systems can be used to communicate both data and voice. LTE Advanced systems can communicate digital voice communications. This can be performed using
25 different standards including Internet Protocol (IP) Multimedia Subsystem (IMS) multimedia telephony (MMTel) and Voice over IMS over LTE (VoLTE). VoLTE can provide voice communications using packet switched network, which can provide many advantages over voice communications using a traditional circuit switched network.

30 BRIEF DESCRIPTION OF THE DRAWINGS

[0004] Features and advantages of the disclosure will be apparent from the detailed

description which follows, taken in conjunction with the accompanying drawings, which together illustrate, by way of example, features of the disclosure; and, wherein:

[0005] FIG. 1 depicts functionality of Radio Access Network (RAN) congestion detection with UE initiated codec rated adaptation, in accordance with an example;

5 [0006] FIG. 2 illustrates user equipment (UE)-evolved Node B(eNB) interaction to adapt uplink (UL) codec bitrate for voice based on UL bandwidth available at radio level, in accordance with an example;

[0007] FIG. 3 depicts functionality of UE-eNB interaction to adapt downlink (DL) codec bitrate for voice based on DL bandwidth available at radio level, in accordance
10 with an example;

[0008] FIG. 4 illustrates RAN congestion detection with network initiated codec rate adaptation, in accordance with an example;

[0009] FIG. 5 depicts functionality of an apparatus of a UE operable to determine a codec bit rate, in accordance with an example;

15 [0010] FIG. 6 depicts functionality of an apparatus of an internet protocol (IP) Multimedia Subsystem (IMS) operable to determine a codec bit rate, in accordance with an example;

[0011] FIG. 7 depicts a flowchart of a machine readable storage medium having instructions embodied thereon for encoding data at an evolved Node B (eNB), in
20 accordance with an example;

[0012] FIG. 8 illustrates example components of a device, in accordance with an example; and

[0013] FIG. 9 illustrates a diagram of a wireless device (e.g., UE) in accordance with an example.

25 [0014] Reference will now be made to the exemplary embodiments illustrated, and specific language will be used herein to describe the same. It will nevertheless be understood that no limitation of the scope of the technology is thereby intended.

DETAILED DESCRIPTION

[0015] Before the present technology is disclosed and described, it is to be understood that this technology is not limited to the particular structures, process actions, or materials disclosed herein, but is extended to equivalents thereof as would be recognized by those ordinarily skilled in the relevant arts. It should also be understood that terminology employed herein is used for the purpose of describing particular examples only and is not intended to be limiting. The same reference numerals in different drawings represent the same element. Numbers provided in flow charts and processes are provided for clarity in illustrating actions and operations and do not necessarily indicate a particular order or sequence.

EXAMPLE EMBODIMENTS

[0016] An initial overview of technology embodiments is provided below and then specific technology embodiments are described in further detail later. This initial summary is intended to aid readers in understanding the technology more quickly but is not intended to identify key features or essential features of the technology nor is it intended to limit the scope of the claimed subject matter.

[0017] Voice over IMS over LTE (VoLTE) is a key feature in LTE to provide voice service over the packet-switched (PS) network. Further, VoLTE allows an operator to replace circuit-switched services over 2G/3G communication systems. VoLTE has been commercially launched by many operators worldwide recently. As such, there are many embodiments and examples that utilize VoLTE as a key feature. Based on the experiences made so far in live networks, VoLTE can provide significant advantages over the use of voice over circuit switched technologies. However, there are some areas of networks using VoLTE in which there can be further improvements.

[0018] One problem that has become apparent is the limited possibility to control the codec type and codec bitrate used during IMS voice (VoLTE) and video call (ViLTE) based on the radio link characteristics. Often the eNB cannot provide an indication to adapt the codec bitrate based on the available bandwidth at the radio level. Therefore, it is important to solve how to enable a VoLTE system to enable the eNB and/or UE to adapt

the video codec type and codec bitrate adaptation based on an available LTE bandwidth in both the uplink (UL) and downlink (DL).

[0019] In another example, the eNB can set an explicit congestion notification bit in the IP header to indicate to the UE that there is an apparent congestion situation.

5 However, this event may not distinguish between UL and DL congestion. In addition, the use of the explicit congestion notification bit does not work efficiently and can be relatively slow for half duplex UL only voice. The use of the explicit congestion notification bit necessitates the eNodeB to perform packet inspection for setting the ECN bits. In addition, the explicit congestion notification bit is either on or off and does not
10 support finer granularity in adaptation.

[0020] In one example, enhancements are disclosed to enable VoLTE codec type and codec rate selection and changes over LTE. Similarly, enhancements to video codec adaptation Video over IMS over LTE (ViLTE) are also disclosed.

[0021] In another example, an evolved Node B (eNB) can control the codec type and
15 codec bitrate to be used during VoLTE, or video over IMS over LTE (ViLTE). The VoLTE or ViLTE codec type and codec bitrate adaptation can be based on the available LTE bandwidth in both the UL and the DL.

[0022] In another example, the eNB can set the Explicit Congestion Notification (ECN) bit in the IP header to indicate to the UE that there is a congestion situation. The
20 eNB can be configured to perform packet inspection for setting the ECN bits.

[0023] The present technology describes methods for a dynamic indication from the eNB to the UE of the available bandwidth at radio level for uplink (UL) and downlink (DL), wherein a VoLTE/ViLTE codec type and codec bitrate adaptation is enabled, based on the available LTE bandwidth in both uplink and downlink.

25 [0024] In one example the eNB can dynamically notify the user equipment (UE) of the radio bit rate for the logical channel in uplink that has been configured to carry the data for voice or video. The recommended bit rate for the logical channel can also be selected for the downlink that has been configured to carry the data for voice or video.

[0025] In another embodiment, the eNB can determine dynamically that the UL
30 prioritized bitrate and the DL recommended prioritized bitrate are based on the radio

condition and the number users and UEs that the eNB serves. The UL traffic can be based on a UL radio bit rate indication, and the UE can determine the appropriate codec type and codec bitrate to apply. The DL traffic can be based on the DL recommended radio bit rate indication, and the UE can indicate the remote peer or media gateway of what should
5 be the appropriate codec type and codec bitrate to apply due to the bandwidth limitation on the local DL radio link.

[0026] In another example, the notification of the available bandwidth can be done with radio resource control (RRC) signaling or using in-band signaling. For instance, the notification can be done using a new media access control (MAC) control element.

10 [0027] In another embodiment, the UE can notify the eNB of the preferred codec bitrate. Based on the selected codec type and codec bitrate at a telephone call setup or during an ongoing telephone call, and also based on the voice or video quality and the redundancy used, the UE can dynamically request bandwidth adaptation for the voice or video bearer.

15 [0028] In another embodiment, the notification of the preferred codec bitrate via the UE to the eNB can be done with layer three (L3) signaling or using in-band signaling, such as a new MAC control element.

[0029] In another embodiment, the eNB can dynamically notify the UE of the available bandwidth for the IMS voice and/or video bearer and the UE can translate this
20 bandwidth into a codec bitrate. The functionality of this embodiment can be applicable for UL and DL communication, and can dynamically adapt the codec bitrate to the radio condition and available bandwidth through an increase or decrease of the bitrate. In addition, the functionality can be applicable for half-duplex and full-duplex operation. In one example, there can be an instance where there is not a need for packet inspection.

25 [0030] In another example, a message can be communicated via L3 signaling by using an existing RRC control message or a new RRC control message to notify the UE of the available bandwidth (i.e. prioritized bit rate in the UL or a recommended prioritized bit rate in the DL) for a specific bearer. The message can also be sent via in-band signaling by using one or more of a new MAC control element and an existing MAC
30 control element. In one embodiment, the available bandwidth can be applied separately for the UL and the DL.

- [0031] In another example, a conversion table can be utilized for the UE to determine a codec bitrate based on the available bandwidth as notified by the eNB. The table can indicate which codec type, codec bitrate and redundancy scheme to apply to satisfy a determined bandwidth. Accordingly, the table below indicates the codec bit rate for an
- 5 Adaptive Multi-rate (AMR) narrowband (NB) codec, an Adaptive Multi-rate (AMR) wideband (WB) codec, an Enhanced Voice Services (EVS) codec, and an example of the relationship between the codec type, the sampling rate, and the codec bitrate.

Codec name	Sampling Rate (kHz)	bit rates (Kbits/sec)
EVS		
	8k, 16k	5.9
	8k, 16k	7.2
	8k, 16k	8
	8k, 16k, 32k	9.6
	8k, 16k, 32k	13.2
	8k, 16k, 32k, 48k	16.4
	8k, 16k, 32k, 48k	24.4
	16k, 32k, 48k	32
	16k, 32k, 48k	48
	16k, 32k, 48k	64
	16k, 32k, 48k	96
	16k, 32k, 48k	128
AMR NB		
	8k	12.2
	8k	10.2
	8k	7.95
	8k	7.4
	8k	6.7
	8k	5.9
	8k	5.15
	8k	4.75
AMR WB		
	16k	6.6
	16k	8.85
	16k	12.65
	16k	14.25
	16k	15.85
	16k	18.25
	16k	19.85
	16k	23.05

	16k	23.85
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[0032] In the above table, the codec type can bit rate can be selected in such a way that the computation of bandwidth ($b=AS$) for a selected codec type and bit rate falls below or is equivalent to the updated/available bandwidth from eNB. Further, the computation of bandwidth ($b=AS$) can also include additional data for a protocol layer header, such as an internet protocol version 4 (IPv4)/IPv6, a User Datagram Protocol (UDP), or a Real-time Transport Protocol (RTP) that can be included in the codec bit rate. The additional data related to the protocol layers header can vary depending of the usage or not of a Robust Header Compression (RoHC).

[0033] In another example, when notifying the UL prioritized bitrate or the DL recommended prioritized bitrate to the UE, the eNB can indicate an explicit bitrate in kilobits/s, or an index to a table of possible bitrates (more compact encoding). This is illustrated in the below table which provides an example of a conversion table between bandwidth index and bitrate value to be used for the eNB to signal available bandwidth for UL and DL.

Bandwidth Index	
Value	Rate (kbps)
0	5
1	8
2	10
3	13
4	15
5	18
6	20
7	25
8	35
9	50
10	70
11	100
12	130
13	...

[0034] In another embodiment a request can be made to a remote peer or to a media gateway to change the bitrate according to the DL bandwidth available for the local UE.

The local UE can use RTP Codec Mode Request (CMR) to notify the peer UE/ media gateway to reduce or increase the peer UL codec bit rate based on the available DL bandwidth for the local UE.

5 [0035] In another embodiment where in-band rate adaptation using RTP CMR is not possible, the local UE can trigger session update procedure using a Session Initiation Protocol (SIP) re-INVITE to negotiate the new preferred codec and the bit rate.

[0036] In another example, there can be an introduction of a message for a UE to notify the eNB of the preferred codec bitrate for VoLTE or ViLTE. The UE can indicate dynamically the preferred codec bitrate according to the codec type, codec bitrate and
10 redundancy scheme the UE determines to apply. The decision can be related to the observed voice/video quality level, packet loss rate or jitter level. The UE can also signal the preferred codec bitrate to the eNB using Radio Resource Control (RRC) signaling or in-band signaling (e.g. using a new MAC control element).

[0037] FIG. 1, provides one illustration of the codec bitrate adaptation 100 based on
15 eNB signaling to notify the UL and DL available bandwidth. In one embodiment, a first UE 110 can transmit media data such as speech and an in-band signal to a second UE 150 via a codec mode request (CMR). Wherein a bit rate indication, which can be decoded at the IMS, received for each of an uplink and downlink radio link between a first UE and a second UE.

20 [0038] In another embodiment the first UE 110, can transmit an adjustment request of the UL bitrate to a second UE 150, using the CMR 140 or a Re-INVITE. Additionally, the second UE 150 in some embodiments can be a remote UE. An eNB 120 can forward the CMR 140 or a SIP re-invite to a second UE 150. The transmission via the eNB can be a control flow utilized to indicate the UL/DL available bandwidth at the radio level. The
25 transmission via the CMR 140 and eNB 120 can be supported by a compatible network 130. Once the transmission is received by the second UE 150, the UE can adjust the UL bitrate using the CMR 140. The second UE 150, can then transmit, via the CMR 140 and eNB 120, an indication of the UL and DL available bandwidth at radio level. For congestion detection within this embodiment, RRC and MAC signaling can be used for
30 congestion detection instead of ECN. The eNB provides (based on radio resource usage, radio link quality, number of user), a bandwidth indicate to the UE 110. Based on this

information, the UE can determine the appropriate codec type and codec rate to apply for downlink. If some adaptation is determined, UE 110 can send a request to adapt codec rate (using in-band signaling with CMR) to change the codec type using SDP negotiation with SIP Re-INVITE message. When receiving the message, UE150 will perform the
5 codec rate or codec type adaption

[0039] In one embodiment, the CMR and the Re-INVITE can be two different procedures. The CMR can be an in-band signaling and is convey for instance using RTCP report. The Re-INVITE is a SIP signaling message. It can be triggered by the control plane, whereas in-band is for the data plane. The CMR in contrast can be allowed to
10 modify the codec rate among already negotiated codec rates. In addition, the RE-INVITE can be configured to renegotiate the codec type or the set of supported codec rate.

[0040] FIG. 2 depicts an example UE-eNB communication to adapt a UL codec bitrate for voice that is based on the detected UL bandwidth available at the radio level. The chart 200, displays an example of transmissions between a UE 210 and an eNB 220.
15 The data radio bearer (DRB) for VoLTE can be established to send UL voice data with a codec rate X. Upon a determination that there is UL facing congestion, the UL bandwidth allocation can be reduced, and a new prioritized bitrate indicator can be sent to the UE 210 from the eNB 220. The new prioritized bitrate indicator can also be an UL radio bandwidth indication. In one example, the new prioritized bitrate indicator can be an IMS
20 Voice DRB UL bandwidth (BW) indication. The UE 210 can then use the prioritized bitrate indicator to identify the possible codec rate, and send voice data with the new codec rate. The UL voice data can then be communicated, with the new codec rate Y, from the UE 210, to the eNB 220.

[0041] FIG. 3 depicts an exemplary UE-eNB interaction 300 to adapt a DL codec
25 bitrate for voice based on DL available bandwidth at the radio level, between a first UE (UE1) 310, an eNB 320, a media gateway (GW) 330 and a second UE (UE2) 340. UE1 310 interacts with the eNB 320, wherein a DRB for VoLTE can be established, and DL voice data can be sent with codec rate X. Within the eNB 320, in the case that DL congestion is faced, DL bandwidth allocation can be reduced and a new desired DL
30 prioritized bitrate indicator can be sent from the eNB 320 to UE1 310. UE1 310 can then inform peer UE2 340 or media gateway 330 to reduce a codec rate for UE2 340 uplink

voice. A CMR for a lower bitrate can be sent from UE1 to the media gateway 340. The media gateway 330, can either send audio data to UE1 with the requested bitrate, or propagate the CMR to provide an indication to UE2 340. UE2 340 can use the CMR indication to send audio data with the requested bitrate to UE1 310.

5 [0042] FIG. 4 illustrates another example where the eNB 420 informs the IMS core network/media gateway 440 instead of the UE 450 of the available UL/DL bandwidth. The media gateway 440 can then trigger the codec bitrate adaptation based on indications received via the eNB 420. A first UE 410 can transmit media data and in-band signals for CMR 430, via the eNB 420. The CMR request from the first UE 410 via the eNB 420 is
10 then transmitted to the IMS core network/media gateway 440. The CMR 430 transmission between the eNB 420 and the IMS 440 can use network specific signaling based on an existing interface or a new interface for congestion detection, or can utilize ECN. The IMS 440, can adjust the bitrate by sending a CMR request 430 or Re-invite to the first UE 410 or a second UE 450. The first UE 410 and the second UE 450 can further
15 dynamically adjust an UL bitrate based on the CMR request. In this use case, eNB 420 notified to the media gateway what is the available bandwidth for UL and DL. The Media Gateway 440 the sends the notification information to both UEs 410/450 with is the codec rate to apply using CMR 430. Another example provides functionality 500 of an apparatus of a UE operable to determine a codec bit rate, as shown in FIG. 5. The apparatus of the
20 UE can comprise one or more processors configured to decode, at the UE, a bit rate indication received for each of an uplink and a downlink radio link between the UE and evolved node B (eNB), as shown in block 510. The apparatus of the UE can comprise one or more processors configured to select, a voice over Internet Protocol (IP) Multimedia Subsystem (IMS) over Long Term Evolution (LTE) (VoLTE) or video over
25 IMS over LTE (ViLTE) codec and codec rate for uplink (UL) VoLTE or UL ViLTE based on the bit rate indication received, as shown in block 520. The apparatus of the UE can also comprise one or more processors configured to apply the selected codec for uplink VoLTE or ViLTE transmission to the eNB based on the received bit rate indication, as shown in block 530. A memory can be coupled to and/or interface with the one or more
30 processors. The memory can be configured to store the bit rate indication.

[0043] In one embodiment, the radio link bit rate indication for the UL can be a UL prioritized bitrate indication. For the downlink, the bitrate indication can be a downlink

recommended radio bit rate indication. The bit rate indication can be received via a radio resource control (RRC) link with the eNB or via a media access control (MAC) control element (CE).

[0044] In one embodiment, the one or more processors are configured to encode, at the UE for the downlink radio link, a codec type indication and a codec bit rate for transmission to one or more of a remote peer or a media gateway to enable the remote peer or media gateway to use the indicated codec type and the codec bit rate for VoLTE or ViLTE. In another embodiment, the UE can dynamically request bandwidth adaptation for a VoLTE or ViLTE. The UE can also notify the eNB of the selected codec bitrate of a voice over or video bearer for VoLTE or ViLTE.

[0045] In one embodiment, the notification to the eNB can be transmitted with Layer 3 (L3) signaling or using a new media access control (MAC) control element (CE). The L3 signaling may be transmitted using an existing radio resource control (RRC) message or a new RRC control message.

[0046] Another example provides functionality 600 of an apparatus of an internet protocol (IP) Multimedia Subsystem (IMS) operable to determine a codec bit rate, as shown in FIG. 6. The apparatus of the IMS can comprise one or more processors configured to Decode at the IMS a bit rate indication received for each of an uplink and downlink radio link between a first user equipment (UE) and an evolved Node B (eNB) 610. The processors can be further configured to Encode at the IMS a Codec Mode Request (CMR) to indicate to a second UE an increase or a decrease of the uplink codec bit rate of the second UE to enable the first UE and second UE to select a voice over Internet Protocol (IP) Multimedia Subsystem (IMS) over Long Term Evolution (LTE) (VoLTE) or video over IMS over LTE (ViLTE) codec 620. The apparatus of the IMS can further comprise memory operable to interface with the one or more processors and store the bitrate indication in the memory. In addition, the UE can use the UL radio bandwidth indication to adapt to its own UL audio codec rate. Also, the UE can use the DL radio bandwidth indication and build a CMR or a SIP re-INITE to notify the peer UE to modify its UL codec rate or to re-negotiate the codec type.

[0047] In one example, the apparatus of the IMS can further comprise a bit rate indication that is received at the IMS based on the radio link between an evolved Node B

(eNB) and at least one of the first UE and the second UE.

[0048] In another example, the apparatus of the IMS can further comprise a bit rate indication that is based on one of a half-duplex and a full duplex connection between the eNB and one of the first UE and the second UE.

5 [0049] In another example, the apparatus of the IMS can further comprise a bit rate indication that is received by the IMS, based on available bandwidth at radio level for an uplink channel and a downlink channel and determines a bandwidth for data transmission over logical channels configured for voice or video communication.

[0050] In another example, the apparatus of the IMS can further comprise a bit rate
10 indication that is received by the IMS can be determined based on the radio link or a number of UEs supported by an eNB.

[0051] In another example, the apparatus of the IMS can further comprise a bit rate indication that is received by the IMS via a radio resource control (RRC) communication or a media access control (MAC) communication.

15 [0052] In another example, the apparatus of the IMS can further comprise a bit rate indication for the uplink wherein there is an uplink radio bit rate indication, and for the downlink wherein there is a downlink recommended radio bit rate indication.

[0053] In another example, the apparatus of the IMS can dynamically adjust the
20 codec bit rate by transmitting Codec Mode Requests (CMR) to the first UE and the second UE.

[0054] In another example, the apparatus of the IMS can have a codec bit rate that is applied separately for uplink and downlink.

[0055] Another example provides at least one machine readable storage medium
having instructions 700 embodied thereon for encoding data at an evolved Node B (eNB),
25 as shown in FIG. 7. The instructions can be executed on a machine, where the instructions are included on at least one computer readable medium or one non-transitory machine readable storage medium. The instructions when executed perform encoding, a bit rate indication received for each of an uplink and a downlink radio link between the UE and eNB, as shown in block 710. The instructions when executed further perform the
30 operation of receiving a selected voice over Internet Protocol (IP) Multimedia Subsystem

(IMS) over Long Term Evolution (LTE) (VoLTE) or video over IMS over LTE (ViLTE) codec for uplink VoLTE or ViLTE, as shown in block 720. The instructions, when executed, additionally perform the operation of applying the selected codec for uplink VoLTE or ViLTE transmission to the eNB based on the received bit rate indication, as shown in block 730.

[0056] In another example, the at least one machine readable storage medium can further comprise instructions, that when executed by one or more processors at the eNB, can request a remote peer to change the bitrate according to a downlink bandwidth for the UE; and, introduce a message for the UE to notify the eNB of the selected codec bitrate for the VoLTE or ViLTE.

[0057] In another example, the at least one machine readable storage can possess a selected codec. Wherein, the codec selected is a computation of bandwidth falls below or equivalent to the available bandwidth from the eNB.

[0058] In another example, the at least one machine readable storage medium can have a computation of bandwidth. Wherein, the computation of bandwidth includes additional data for protocol layers of the codec bit rate comprising internet protocol version 4 (IPv4), internet protocol version 6 (IPv6), user datagram protocol (UDP), and real-time transport protocol (RTP).

[0059] In another example, the at least one machine readable storage medium can have a notification of the available code bitrate in uplink or downlink. Wherein, the available code bitrate is received and transmitted by a radio resource control (RRC) or a media access control (MAC) message. FIG. 8 illustrates example components of a device in accordance with some embodiments. In some embodiments, the device 800 may include application circuitry 802, baseband circuitry 804, Radio Frequency (RF) circuitry 806, front-end module (FEM) circuitry 808, and one or more antennas 810, coupled together at least as shown. The components of the illustrated device 800 may be included a UE or a RAN node. In some embodiments, the device 800 may include less elements (e.g., a RAN node may not utilize application circuitry 802, and instead include a processor/controller to process IP data received from an EPC). In some embodiments, the device 800 may include additional elements such as, for example, memory/storage, display, camera, sensor, and/or input/output (I/O) interface. In other embodiments, the

components described below may be included in more than one device (e.g., said circuitries may be separately included in more than one device for Cloud-RAN (C-RAN) implementations).

[0060] The application circuitry 802 may include one or more application processors.

5 For example, the application circuitry 802 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) may include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors may be coupled with and/or may include memory/storage and may be configured to execute instructions stored in the
10 memory/storage to enable various applications and/or operating systems to run on the system. In some embodiments, processors of application circuitry 802 may process IP data packets received from an EPC.

[0061] The baseband circuitry 804 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 804 may

15 include one or more baseband processors and/or control logic to process baseband signals received from a receive signal path of the RF circuitry 806 and to generate baseband signals for a transmit signal path of the RF circuitry 806. Baseband processing circuitry 804 may interface with the application circuitry 802 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 806. For example, in
20 some embodiments, the baseband circuitry 804 may include a second generation (2G) baseband processor 804a, third generation (3G) baseband processor 804b, fourth generation (4G) baseband processor 804c, and/or other baseband processor(s) 804d for other existing generations, generations in development or to be developed in the future (e.g., fifth generation (5G), 6G, etc.). The baseband circuitry 804 (e.g., one or more of
25 baseband processors 804a-d) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 806. In other embodiments, some or all of the functionality of baseband processors 804a-d may be included in modules stored in the memory 804g and executed via a Central Processing Unit (CPU) 804e. The radio control functions may include, but are not limited to, signal
30 modulation/demodulation, encoding/decoding, radio frequency shifting, etc. In some embodiments, modulation/demodulation circuitry of the baseband circuitry 804 may include Fast-Fourier Transform (FFT), precoding, and/or constellation

mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 804 may include convolution, tail-biting convolution, turbo, Viterbi, and/or Low Density Parity Check (LDPC) encoder/decoder functionality. Embodiments of modulation/demodulation and encoder/decoder functionality are not limited to these examples and may include other suitable functionality in other embodiments.

[0062] In some embodiments, the baseband circuitry may include one or more audio digital signal processor(s) (DSP) 804f. The audio DSP(s) 804f may include elements for compression/decompression and echo cancellation and may include other suitable processing elements in other embodiments. Components of the baseband circuitry may be suitably combined in a single chip, a single chipset, or disposed on a same circuit board in some embodiments. In some embodiments, some or all of the constituent components of the baseband circuitry 804 and the application circuitry 802 may be implemented together such as, for example, on a system on a chip (SOC).

[0063] In some embodiments, the baseband circuitry 804 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 804 may support communication with an evolved universal terrestrial radio access network (EUTRAN) and/or other wireless metropolitan area networks (WMAN), a wireless local area network (WLAN), a wireless personal area network (WPAN). Embodiments in which the baseband circuitry 804 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

[0064] RF circuitry 806 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 806 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 806 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 808 and provide baseband signals to the baseband circuitry 804. RF circuitry 806 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 804 and provide RF output signals to the FEM circuitry 808 for transmission.

[0065] In some embodiments, the RF circuitry 806 may include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 806 may include mixer circuitry 806a, amplifier circuitry 806b and filter circuitry 806c. The transmit signal path of the RF circuitry 806 may include filter circuitry 806c and mixer circuitry 806a. RF circuitry 806 may also include synthesizer circuitry 806d for synthesizing a frequency for use by the mixer circuitry 806a of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 806a of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 808 based on the synthesized frequency provided by synthesizer circuitry 806d. The amplifier circuitry 806b may be configured to amplify the down-converted signals and the filter circuitry 806c may be a low-pass filter (LPF) or band-pass filter (BPF) configured to remove unwanted signals from the down-converted signals to generate output baseband signals. Output baseband signals may be provided to the baseband circuitry 804 for further processing. In some embodiments, the output baseband signals may be zero-frequency baseband signals, although this is not a necessity. In some embodiments, mixer circuitry 806a of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

[0066] In some embodiments, the mixer circuitry 806a of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 806d to generate RF output signals for the FEM circuitry 808. The baseband signals may be provided by the baseband circuitry 804 and may be filtered by filter circuitry 806c. The filter circuitry 806c may include a low-pass filter (LPF), although the scope of the embodiments is not limited in this respect.

[0067] In some embodiments, the mixer circuitry 806a of the receive signal path and the mixer circuitry 806a of the transmit signal path may include two or more mixers and may be arranged for quadrature downconversion and/or upconversion respectively. In some embodiments, the mixer circuitry 806a of the receive signal path and the mixer circuitry 806a of the transmit signal path may include two or more mixers and may be arranged for image rejection (e.g., Hartley image rejection). In some embodiments, the mixer circuitry 806a of the receive signal path and the mixer circuitry 806a may be arranged for direct downconversion and/or direct upconversion, respectively. In some embodiments, the mixer circuitry 806a of the receive signal path and the mixer circuitry

806a of the transmit signal path may be configured for super-heterodyne operation.

[0068] In some embodiments, the output baseband signals and the input baseband signals may be analog baseband signals, although the scope of the embodiments is not limited in this respect. In some alternate embodiments, the output baseband signals and
5 the input baseband signals may be digital baseband signals. In these alternate embodiments, the RF circuitry 806 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 804 may include a digital baseband interface to communicate with the RF circuitry 806.

[0069] In some dual-mode embodiments, a separate radio IC circuitry may be
10 provided for processing signals for each spectrum, although the scope of the embodiments is not limited in this respect.

[0070] In some embodiments, the synthesizer circuitry 806d may be a fractional-N synthesizer or a fractional $N/N+1$ synthesizer, although the scope of the embodiments is not limited in this respect as other types of frequency synthesizers may be suitable. For
15 example, synthesizer circuitry 806d may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

[0071] The synthesizer circuitry 806d may be configured to synthesize an output frequency for use by the mixer circuitry 806a of the RF circuitry 806 based on a frequency input and a divider control input. In some embodiments, the synthesizer
20 circuitry 806d may be a fractional $N/N+1$ synthesizer.

[0072] In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO), although that is not a necessity. Divider control input may be provided by either the baseband circuitry 804 or the applications processor 802 depending on the desired output frequency. In some embodiments, a divider control input
25 (e.g., N) may be determined from a look-up table based on a channel indicated by the applications processor 802.

[0073] Synthesizer circuitry 806d of the RF circuitry 806 may include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some embodiments, the divider may be a dual modulus divider (DMD) and the phase accumulator may be a
30 digital phase accumulator (DPA). In some embodiments, the DMD may be configured to divide the input signal by either N or N+1 (e.g., based on a carry out) to provide a

fractional division ratio. In some example embodiments, the DLL may include a set of cascaded, tunable, delay elements, a phase detector, a charge pump and a D-type flip-flop. In these embodiments, the delay elements may be configured to break a VCO period up into N_d equal packets of phase, where N_d is the number of delay elements in the delay line. In this way, the DLL provides negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

[0074] In some embodiments, synthesizer circuitry 806d may be configured to generate a carrier frequency as the output frequency, while in other embodiments, the output frequency may be a multiple of the carrier frequency (e.g., twice the carrier frequency, four times the carrier frequency) and used in conjunction with quadrature generator and divider circuitry to generate multiple signals at the carrier frequency with multiple different phases with respect to each other. In some embodiments, the output frequency may be a LO frequency (fLO). In some embodiments, the RF circuitry 806 may include an IQ/polar converter.

[0075] FEM circuitry 808 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 810, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 806 for further processing. FEM circuitry 808 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 806 for transmission by one or more of the one or more antennas 810.

[0076] In some embodiments, the FEM circuitry 808 may include a TX/RX switch to switch between transmit mode and receive mode operation. The FEM circuitry may include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry may include a low-noise amplifier (LNA) to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 806). The transmit signal path of the FEM circuitry 808 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 806), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 810).

[0077] In some embodiments, the device 800 comprises a plurality of power saving

mechanisms. If the device 800 is in an RRC_Connected state, where it is still connected to the RAN node as it expects to receive traffic shortly, then it may enter a state known as Discontinuous Reception Mode (DRX) after a period of inactivity. During this state, the device may power down for brief intervals of time and thus save power.

5 [0078] If there is no data traffic activity for an extended period of time, then the device 800 may transition off to an RRC_Idle state, where it disconnects from the network and does not perform operations such as channel quality feedback, handover, etc. The device 800 goes into a very low power state and it performs paging where again it periodically wakes up to listen to the network and then powers down again. The device
10 cannot receive data in this state, in order to receive data, it has to transition back to RRC_Connected state.

[0079] An additional power saving mode may allow a device to be unavailable to the network for periods longer than a paging interval (ranging from seconds to a few hours). During this time, the device is totally unreachable to the network and may power down
15 completely. Any data sent during this time incurs a large delay and it is assumed the delay is acceptable.

[0080] Processors of the application circuitry 802 and processors of the baseband circuitry 804 may be used to execute elements of one or more instances of a protocol stack. For example, processors of the baseband circuitry 804, alone or in combination,
20 may be used execute Layer 3, Layer 2, and/or Layer 1 functionality, while processors of the application circuitry 804 may utilize data (e.g., packet data) received from these layers and further execute Layer 4 functionality (e.g., transmission communication protocol (TCP) and user datagram protocol (UDP) layers). As referred to herein, Layer 3 may comprise a radio resource control (RRC) layer, described in further detail below. As
25 referred to herein, Layer 2 may comprise a medium access control (MAC) layer, a radio link control (RLC) layer, and a packet data convergence protocol (PDCP) layer, described in further detail below. As referred to herein, Layer 1 may comprise a physical (PHY) layer of a UE/RAN node, described in further detail below.

[0081] FIG. 9 provides an example illustration of the wireless device, such as a user
30 equipment (UE), a mobile station (MS), a mobile wireless device, a mobile communication device, a tablet, a handset, or other type of wireless device. The wireless

device can include one or more antennas configured to communicate with a node, macro node, low power node (LPN), or, transmission station, such as a base station (BS), an evolved Node B (eNB), a baseband processing unit (BBU), a remote radio head (RRH), a remote radio equipment (RRE), a relay station (RS), a radio equipment (RE), or other type of wireless wide area network (WWAN) access point. The wireless device can be configured to communicate using at least one wireless communication standard such as, but not limited to, 3GPP LTE, WiMAX, High Speed Packet Access (HSPA), Bluetooth, and WiFi. The wireless device can communicate using separate antennas for each wireless communication standard or shared antennas for multiple wireless communication standards. The wireless device can communicate in a wireless local area network (WLAN), a wireless personal area network (WPAN), and/or a WWAN. The wireless device can also comprise a wireless modem. The wireless modem can comprise, for example, a wireless radio transceiver and baseband circuitry (e.g., a baseband processor). The wireless modem can, in one example, modulate signals that the wireless device transmits via the one or more antennas and demodulate signals that the wireless device receives via the one or more antennas.

[0082] FIG. 9 also provides an illustration of a microphone and one or more speakers that can be used for audio input and output from the wireless device. The display screen can be a liquid crystal display (LCD) screen, or other type of display screen such as an organic light emitting diode (OLED) display. The display screen can be configured as a touch screen. The touch screen can use capacitive, resistive, or another type of touch screen technology. An application processor and a graphics processor can be coupled to internal memory to provide processing and display capabilities. A non-volatile memory port can also be used to provide data input/output options to a user. The non-volatile memory port can also be used to expand the memory capabilities of the wireless device. A keyboard can be integrated with the wireless device or wirelessly connected to the wireless device to provide additional user input. A virtual keyboard can also be provided using the touch screen.

Examples

[0083] The following examples pertain to specific technology embodiments and point out specific features, elements, or actions that can be used or otherwise combined in

achieving such embodiments.

[0084] Example 1 includes an apparatus of a User Equipment (UE) operable to determine a codec bit rate, the apparatus comprising: one or more processors configured to: decode, at the UE, a bit rate indication received for each of an uplink and a downlink radio link between the UE and evolved node B (eNB); select, a voice over Internet Protocol (IP) Multimedia Subsystem (IMS) over Long Term Evolution (LTE) (VoLTE) or video over IMS over LTE (ViLTE) codec for uplink (UL) VoLTE or UL ViLTE; and apply the selected codec for uplink VoLTE or ViLTE transmission to the eNB based on the received bit rate indication; and memory coupled to the one or more processors, wherein the memory is configured to store the bit rate indication.

[0085] Example 2 includes, the apparatus of example 1, wherein the bit rate indication: for the uplink is an uplink radio bit rate indication; and for the downlink is a downlink recommended radio bit rate indication.

[0086] Example 3 includes the apparatus of example 1 or 2, wherein the bit rate indication is received via a radio resource control (RRC) link with the eNB or via a media access control (MAC) control element (CE).

[0087] Example 4 includes the apparatus of example 1, wherein the one or more of the processors are configured to encode, at the UE for the downlink radio link, a codec type indication and a codec bit rate for transmission to one or more of a remote peer or a media gateway to enable the remote peer or media gateway to use the indicated codec type and the codec bit rate for VoLTE or ViLTE.

[0088] Example 5 includes the apparatus of example 1 or 4, wherein the UE dynamically request bandwidth adaptation for a voice over or video bearer.

[0089] Example 6 includes the apparatus of example 1, wherein the one or more of the processors are further configured to encode the selected codec bitrate for VoLTE or ViLTE for transmission to an eNB.

[0090] Example 7 includes the apparatus of example 6 wherein a notification to the eNB is transmitted with Layer 3 (L3) signalling or using a new media access control (MAC) control element (CE).

[0091] Example 8 includes the apparatus of example 6, wherein the L3 signalling is

transmitted by using an existing radio resource control (RRC) message or a new RRC control message.

[0092] Example 9 includes an apparatus of an IP Multimedia Subsystem (IMS) operable to determine a codec bit rate, the apparatus comprising: one or more processors
5 configured to: decode at the IMS a bit rate indication received for each of an uplink and downlink radio link between a first user equipment (UE) and an evolved Node B (eNB); and encode at the IMS a Codec Mode Request (CMR) to indicate to a second UE an increase or a decrease of the uplink codec bit rate of the second UE to enable the first UE and second UE to select a voice over Internet Protocol (IP) Multimedia Subsystem (IMS)
10 over Long Term Evolution (LTE) (VoLTE) or video over IMS over LTE (ViLTE) codec; and memory operable to interface with the one or more processors and store the bitrate indication in the memory.

[0093] Example 10 includes the apparatus of example 9, wherein the bit rate indication is received at the IMS based on the radio link between an evolved Node B
15 (eNB) and at least one of the first UE and the second UE.

[0094] Example 11 includes the apparatus of example 10, wherein the bit rate indication is based on one of a half-duplex and a full duplex connection between the eNB and one of the first UE and the second UE.

[0095] Example 12 includes the apparatus of example 10, wherein the IMS receives
20 the bit rate indication based on available bandwidth at radio level for an uplink channel and a downlink channel and determines a bandwidth for data transmission over logical channels configured for voice or video communication.

[0096] Example 13 includes the apparatus of example 10, wherein the bit rate indication received at the IMS is determined based on the radio link or a number of UEs
25 supported by an eNB.

[0097] Example 14 includes the apparatus of example 9 or 10, wherein the bit rate indication is received at the IMS via a radio resource control (RRC) communication or a media access control (MAC) communication.

[0098] Example 15 includes the apparatus of example 9, wherein the bit rate
30 indication: for the uplink is an uplink radio bit rate indication; and for the downlink is a

downlink recommended radio bit rate indication.

[0099] Example 16 includes the apparatus of example 9 or 10, wherein the media gateway dynamically adjusts the codec bit rate by transmitting Codec Mode Requests (CMR) to the first UE and the second UE.

5 [00100] Example 17 includes the apparatus of example 9, wherein the codec bit rate is applied separately for uplink and downlink.

[00101] Example 18 includes at least one machine readable storage medium having instructions embodied thereon for encoding data at an evolved Node B (eNB), the instructions when executed by one or more processors at the eNB perform the following:
10 encoding, a bit rate indication received for each of an uplink and a downlink radio link between the UE and eNB; receiving a selected voice over Internet Protocol (IP) Multimedia Subsystem (IMS) over Long Term Evolution (LTE) (VoLTE) or video over IMS over LTE (ViLTE) codec for uplink VoLTE or ViLTE; and applying the selected codec for uplink VoLTE or ViLTE transmission to the UE based on the received bit rate
15 indication, wherein the received bit rate indication is configured based on a determined radio resource available by the eNB.

[00102] Example 19 includes the at least one machine readable storage medium in example 18 further comprising instructions, that when executed by one or more processors at the eNB, perform the following: requesting a remote peer to change the
20 bitrate according to a downlink bandwidth for the UE; and, introducing a message for the UE to notify the eNB of the selected codec bitrate for the VoLTE or ViLTE.

[00103] Example 20 includes the at least one machine readable storage medium in example 18 or 19, wherein the codec selected is a computation of bandwidth falls below or equivalent to the available bandwidth from the eNB.

25 [00104] Example 21 includes the at least one machine readable storage medium in example 19, wherein the computation of bandwidth includes additional data for protocol layers of the codec bit rate comprising internet protocol version 4 (IPv4), internet protocol version 6 (IPv6), user datagram protocol (UDP), and real-time transport protocol (RTP).

[00105] Example 22 includes the at least one machine readable storage medium in
30 example 19, wherein the notification of the available code bitrate in uplink or downlink is

received and transmitted by a radio resource control (RRC) or a media access control (MAC) message.

[00106] Example 23 an apparatus of a User Equipment (UE) operable to determine a codec bit rate, the apparatus comprising: one or more processors configured to: decode, at the UE, a bit rate indication received for each of an uplink and a downlink radio link between the UE and evolved node B (eNB); select, a voice over Internet Protocol (IP) Multimedia Subsystem (IMS) over Long Term Evolution (LTE) (VoLTE) or video over IMS over LTE (ViLTE) codec for uplink (UL) VoLTE or UL ViLTE; and apply the selected codec for uplink VoLTE or ViLTE transmission to the eNB based on the received bit rate indication; and memory coupled to the one or more processors, wherein the memory is configured to store the bit rate indication.

[00107] Example 24 includes the apparatus of example [00106], wherein the bit rate indication: for the uplink is an uplink radio bit rate indication; for the downlink is a downlink recommended radio bit rate indication; and the bit rate indication is received via a radio resource control (RRC) link with the eNB or via a media access control (MAC) control element (CE).

[00108] Example 25 includes the apparatus of example [00106], wherein the one or more of the processors are configured to encode, at the UE for the downlink radio link, a codec type indication and a codec bit rate for transmission to one or more of a remote peer or a media gateway to enable the remote peer or media gateway to use the indicated codec type and the codec bit rate for VoLTE or ViLTE.

[00109] Example 26 includes the apparatus of example [00106] or [00108], wherein the UE: dynamically request bandwidth adaptation for a voice over or video bearer; or a notification to the eNB is transmitted with Layer 3 (L3) signalling or using a new media access control (MAC) control element (CE), wherein the L3 signalling is transmitted by using an existing radio resource control (RRC) message or a new RRC control message.

[00110] Example 27 includes the apparatus of example [00106], wherein the one or more of the processors are further configured to encode the selected codec bitrate for VoLTE or ViLTE for transmission to an eNB.

[00111] Example 28 includes an apparatus of an IP Multimedia Subsystem (IMS) operable to determine a codec bit rate, the apparatus comprising: one or more processors

configured to: decode at the IMS a bit rate indication received for each of an uplink and downlink radio link between a first user equipment (UE) and an evolved Node B (eNB); and encode at the IMS a Codec Mode Request (CMR) to indicate to a second UE an increase or a decrease of the uplink codec bit rate of the second UE to enable the first UE and second UE to select a voice over Internet Protocol (IP) Multimedia Subsystem (IMS) over Long Term Evolution (LTE) (VoLTE) or video over IMS over LTE (ViLTE) codec; and memory operable to interface with the one or more processors and store the bitrate indication in the memory.

[00112] Example 29 includes the apparatus of example [00111], wherein the bit rate indication: is received at the IMS based on the radio link between an evolved Node B (eNB) and at least one of the first UE and the second UE; or the bit rate indication is based on one of a half-duplex and a full duplex connection between the eNB and one of the first UE and the second UE.

[00113] Example 30 includes the apparatus of example [00112], wherein the IMS receives the bit rate indication based on available bandwidth at radio level for an uplink channel and a downlink channel and determines a bandwidth for data transmission over logical channels configured for voice or video communication.

[00114] Example 31 includes the apparatus of example [00112], wherein the bit rate indication received at the IMS is determined based on the radio link or a number of UEs supported by an eNB, or the bit rate indication is received at the IMS via a radio resource control (RRC) communication or a media access control (MAC) communication.

[00115] Example 32 includes the apparatus of example [00111], wherein the bit rate indication: for the uplink is an uplink radio bit rate indication; and for the downlink is a downlink recommended radio bit rate indication.

[00116] Example 33 includes the apparatus of example [00111] or [00112], wherein the media gateway dynamically adjusts the codec bit rate by transmitting Codec Mode Requests (CMR) to the first UE and the second UE, wherein the codec bit rate is applied separately for uplink and downlink.

[00117] Example 34 includes at least one machine readable storage medium having instructions embodied thereon for encoding data at an evolved Node B (eNB), the instructions when executed by one or more processors at the eNB perform the following:

encoding, a bit rate indication received for each of an uplink and a downlink radio link between the UE and eNB; receiving a selected voice over Internet Protocol (IP) Multimedia Subsystem (IMS) over Long Term Evolution (LTE) (VoLTE) or video over IMS over LTE (ViLTE) codec for uplink VoLTE or ViLTE; and applying the selected
5 codec for uplink VoLTE or ViLTE transmission to the UE based on the received bit rate indication, wherein the received bit rate indication is configured based on a determined radio resource available by the eNB.

[00118] Example 35 includes the at least one machine readable storage medium in example [00117] further comprising instructions, that when executed by one or more
10 processors at the eNB, perform the following: requesting a remote peer to change the bitrate according to a downlink bandwidth for the UE; and, introducing a message for the UE to notify the eNB of the selected codec bitrate for the VoLTE or ViLTE.

[00119] Example 36 includes the at least one machine readable storage medium in example [00117] or [00118], wherein the codec selected is a computation of bandwidth
15 falls below or equivalent to the available bandwidth from the eNB, wherein the computation of bandwidth includes additional data for protocol layers of the codec bit rate comprising internet protocol version 4 (IPv4), internet protocol version 6 (IPv6), user datagram protocol (UDP), and real-time transport protocol (RTP).

[00120] Example 37 includes the at least one machine readable storage medium in
20 example [00118], wherein the notification of the available code bitrate in uplink or downlink is received and transmitted by a radio resource control (RRC) or a media access control (MAC) message.

[00121] Example 38 includes an evolved Node B (eNB) operable to encode data, the eNB comprising: means for encoding, a bit rate indication received for each of an uplink
25 and a downlink radio link between the UE and eNB; means for receiving a selected voice over Internet Protocol (IP) Multimedia Subsystem (IMS) over Long Term Evolution (LTE) (VoLTE) or video over IMS over LTE (ViLTE) codec for uplink VoLTE or ViLTE; and means for applying the selected codec for uplink VoLTE or ViLTE transmission to the UE based on the received bit rate indication, wherein the received bit rate indication is
30 configured based on a determined radio resource available by the eNB.

[00122] Example 39 includes the eNB of example [00121] further comprising: means

for requesting a remote peer to change the bitrate according to a downlink bandwidth for the UE; and, means for introducing a message for the UE to notify the eNB of the selected codec bitrate for the VoLTE or ViLTE.

[00123] Example 40 includes the eNB of example [00121] or [00122], wherein the
5 codec selected is a computation of bandwidth falls below or equivalent to the available bandwidth from the eNB.

[00124] Example 41 includes the eNB of example [00122], wherein the computation of bandwidth includes additional data for protocol layers of the codec bit rate comprising internet protocol version 4 (IPv4), internet protocol version 6 (IPv6), user datagram
10 protocol (UDP), and real-time transport protocol (RTP).

[00125] Example 42 includes the eNB of example [00122], wherein the notification of the available code bitrate in uplink or downlink is received and transmitted by a radio resource control (RRC) or a media access control (MAC) message.

[00126] Various techniques, or certain aspects or portions thereof, may take the form of
15 program code (i.e., instructions) embodied in tangible media, such as floppy diskettes, compact disc-read-only memory (CD-ROMs), hard drives, non-transitory computer readable storage medium, or any other machine-readable storage medium wherein, when the program code is loaded into and executed by a machine, such as a computer, the machine becomes an apparatus for practicing the various techniques. In the case of
20 program code execution on programmable computers, the computing device may include a processor, a storage medium readable by the processor (including volatile and non-volatile memory and/or storage elements), at least one input device, and at least one output device. The volatile and non-volatile memory and/or storage elements may be a random-access memory (RAM), erasable programmable read only memory (EPROM),
25 flash drive, optical drive, magnetic hard drive, solid state drive, or other medium for storing electronic data. The node and wireless device may also include a transceiver module (i.e., transceiver), a counter module (i.e., counter), a processing module (i.e., processor), and/or a clock module (i.e., clock) or timer module (i.e., timer). In one example, selected components of the transceiver module can be located in a cloud radio
30 access network (C-RAN). One or more programs that may implement or utilize the various techniques described herein may use an application programming interface (API),

reusable controls, and the like. Such programs may be implemented in a high level procedural or object oriented programming language to communicate with a computer system. However, the program(s) may be implemented in assembly or machine language, if desired. In any case, the language may be a compiled or interpreted language, and
5 combined with hardware implementations.

[00127] As used herein, the term "circuitry" may refer to, be part of, or include an Application Specific Integrated Circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group), and/or memory (shared, dedicated, or group) that execute one or more software or firmware programs, a combinational logic circuit, and/or other
10 suitable hardware components that provide the described functionality. In some embodiments, the circuitry may be implemented in, or functions associated with the circuitry may be implemented by, one or more software or firmware modules. In some embodiments, circuitry may include logic, at least partially operable in hardware.

[00128] It should be understood that many of the functional units described in this
15 specification have been labeled as modules, in order to more particularly emphasize their implementation independence. For example, a module may be implemented as a hardware circuit comprising custom very-large-scale integration (VLSI) circuits or gate arrays, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. A module may also be implemented in programmable hardware devices
20 such as field programmable gate arrays, programmable array logic, programmable logic devices or the like.

[00129] Modules may also be implemented in software for execution by various types of processors. An identified module of executable code may, for instance, comprise one or more physical or logical blocks of computer instructions, which may, for instance, be
25 organized as an object, procedure, or function. Nevertheless, the executables of an identified module may not be physically located together, but may comprise disparate instructions stored in different locations which, when joined logically together, comprise the module and achieve the stated purpose for the module.

[00130] Indeed, a module of executable code may be a single instruction, or many
30 instructions, and may even be distributed over several different code segments, among different programs, and across several memory devices. Similarly, operational data may

be identified and illustrated herein within modules, and may be embodied in any suitable form and organized within any suitable type of data structure. The operational data may be collected as a single data set, or may be distributed over different locations including over different storage devices, and may exist, at least partially, merely as electronic
5 signals on a system or network. The modules may be passive or active, including agents operable to perform desired functions.

[00131] Reference throughout this specification to "an example" or "exemplary" means that a particular feature, structure, or characteristic described in connection with the example is included in at least one embodiment of the present technology. Thus,
10 appearances of the phrases "in an example" or the word "exemplary" in various places throughout this specification are not necessarily all referring to the same embodiment.

[00132] As used herein, a plurality of items, structural elements, compositional elements, and/or materials may be presented in a common list for convenience. However, these lists should be construed as though each member of the list is individually identified as a
15 separate and unique member. Thus, no individual member of such list should be construed as a de facto equivalent of any other member of the same list solely based on their presentation in a common group without indications to the contrary. In addition, various embodiments and example of the present technology may be referred to herein along with alternatives for the various components thereof. It is understood that such
20 embodiments, examples, and alternatives are not to be construed as defacto equivalents of one another, but are to be considered as separate and autonomous representations of the present technology.

[00133] Furthermore, the described features, structures, or characteristics may be combined in any suitable manner in one or more embodiments. In the following
25 description, numerous specific details are provided, such as examples of layouts, distances, network examples, etc., to provide a thorough understanding of embodiments of the technology. One skilled in the relevant art will recognize, however, that the technology can be practiced without one or more of the specific details, or with other methods, components, layouts, etc. In other instances, well-known structures, materials,
30 or operations are not shown or described in detail to avoid obscuring aspects of the technology.

While the forgoing examples are illustrative of the principles of the present technology in one or more particular applications, it will be apparent to those of ordinary skill in the art that numerous modifications in form, usage and details of implementation can be made without the exercise of inventive faculty, and without departing from the principles and
5 concepts of the technology. Accordingly, it is not intended that the technology be limited, except as by the claims set forth below.

CLAIMS

What is claimed is:

1. An apparatus of a User Equipment (UE) operable to determine a codec bit rate,
the apparatus comprising:
 - 5 one or more processors configured to:
 - decode, at the UE, a bit rate indication received for each of an uplink
and a downlink radio link between the UE and evolved node B (eNB);
 - select, a voice over Internet Protocol (IP) Multimedia Subsystem
(IMS) over Long Term Evolution (LTE) (VoLTE) or video over IMS over
10 LTE (ViLTE) codec for uplink (UL) VoLTE or UL ViLTE; and
 - apply the selected codec for uplink VoLTE or ViLTE transmission to
the eNB based on the received bit rate indication; and
 - memory coupled to the one or more processors, wherein the memory is
configured to store the bit rate indication.
- 15 2. The apparatus of claim 1, wherein the bit rate indication:
 - for the uplink is an uplink radio bit rate indication; and
 - for the downlink is a downlink recommended radio bit rate indication.
- 20 3. The apparatus of claim 1 or 2, wherein the bit rate indication is received via a
radio resource control (RRC) link with the eNB or via a media access control
(MAC) control element (CE).
- 25 4. The apparatus of claim 1, wherein the one or more of the processors are
configured to encode, at the UE for the downlink radio link, a codec type
indication and a codec bit rate for transmission to one or more of a remote peer or
a media gateway to enable the remote peer or media gateway to use the indicated
codec type and the codec bit rate for VoLTE or ViLTE.
- 30 5. The apparatus of claim 1 or 4, wherein the UE dynamically request bandwidth
adaptation for a voice over or video bearer.

6. The apparatus of claim 1, wherein the one or more of the processors are further configured to encode the selected codec bitrate for VoLTE or ViLTE for transmission to an eNB.
- 5 7. The apparatus of claim 6 wherein a notification to the eNB is transmitted with Layer 3 (L3) signalling or using a new media access control (MAC) control element (CE).
8. The apparatus of claim 6, wherein the L3 signalling is transmitted by using an
10 existing radio resource control (RRC) message or a new RRC control message.
9. An apparatus of an IP Multimedia Subsystem (IMS) operable to determine a codec bit rate, the apparatus comprising:
one or more processors configured to:
15 decode at the IMS a bit rate indication received for each of an uplink and downlink radio link between a first user equipment (UE) and an evolved Node B (eNB); and
encode at the IMS a Codec Mode Request (CMR) to indicate to a
second UE an increase or a decrease of the uplink codec bit rate of the
20 second UE to enable the first UE and second UE to select a voice over Internet Protocol (IP) Multimedia Subsystem (IMS) over Long Term Evolution (LTE) (VoLTE) or video over IMS over LTE (ViLTE) codec;
and
memory operable to interface with the one or more processors and store
25 the bitrate indication in the memory.
10. The apparatus of claim 9, wherein the bit rate indication is received at the IMS based on the radio link between an evolved Node B (eNB) and at least one of the first UE and the second UE.
30
11. The apparatus of claim 10, wherein the bit rate indication is based on one of a half-duplex and a full duplex connection between the eNB and one of the first UE

and the second UE.

- 5 12. The apparatus of claim 10, wherein the IMS receives the bit rate indication based on available bandwidth at radio level for an uplink channel and a downlink channel and determines a bandwidth for data transmission over logical channels configured for voice or video communication.
- 10 13. The apparatus of claim 10, wherein the bit rate indication received at the IMS is determined based on the radio link or a number of UEs supported by an eNB.
14. The apparatus of claim 9 or 10, wherein the bit rate indication is received at the IMS via a radio resource control (RRC) communication or a media access control (MAC) communication.
- 15 15. The apparatus of claim 9, wherein the bit rate indication:
for the uplink is an uplink radio bit rate indication; and
for the downlink is a downlink recommended radio bit rate indication.
- 20 16. The apparatus of claim 9 or 10, wherein the media gateway dynamically adjusts the codec bit rate by transmitting Codec Mode Requests (CMR) to the first UE and the second UE.
- 25 17. The apparatus of claim 9, wherein the codec bit rate is applied separately for uplink and downlink.
18. At least one machine readable storage medium having instructions embodied thereon for encoding data at an evolved Node B (eNB), the instructions when executed by one or more processors at the eNB perform the following:
encoding, a bit rate indication received for each of an uplink and a
30 downlink radio link between the UE and eNB;

receiving a selected voice over Internet Protocol (IP) Multimedia Subsystem (IMS) over Long Term Evolution (LTE) (VoLTE) or video over IMS over LTE (ViLTE) codec for uplink VoLTE or ViLTE; and
applying the selected codec for uplink VoLTE or ViLTE transmission
to the UE based on the received bit rate indication, wherein the received
bit rate indication is configured based on a determined radio resource
available by the eNB.

19. The at least one machine readable storage medium in claim 18 further comprising instructions, that when executed by one or more processors at the eNB, perform the following:

requesting a remote peer to change the bitrate according to a downlink bandwidth for the UE; and,

introducing a message for the UE to notify the eNB of the selected
codec bitrate for the VoLTE or ViLTE.

20. The at least one machine readable storage medium in claim 18 or 19, wherein the codec selected is a computation of bandwidth falls below or equivalent to the available bandwidth from the eNB.

21. The at least one machine readable storage medium in claim 19, wherein the computation of bandwidth includes additional data for protocol layers of the codec bit rate comprising internet protocol version 4 (IPv4), internet protocol version 6 (IPv6), user datagram protocol (UDP), and real-time transport protocol (RTP).

22. The at least one machine readable storage medium in claim 19, wherein the notification of the available code bitrate in uplink or downlink is received and transmitted by a radio resource control (RRC) or a media access control (MAC) message.

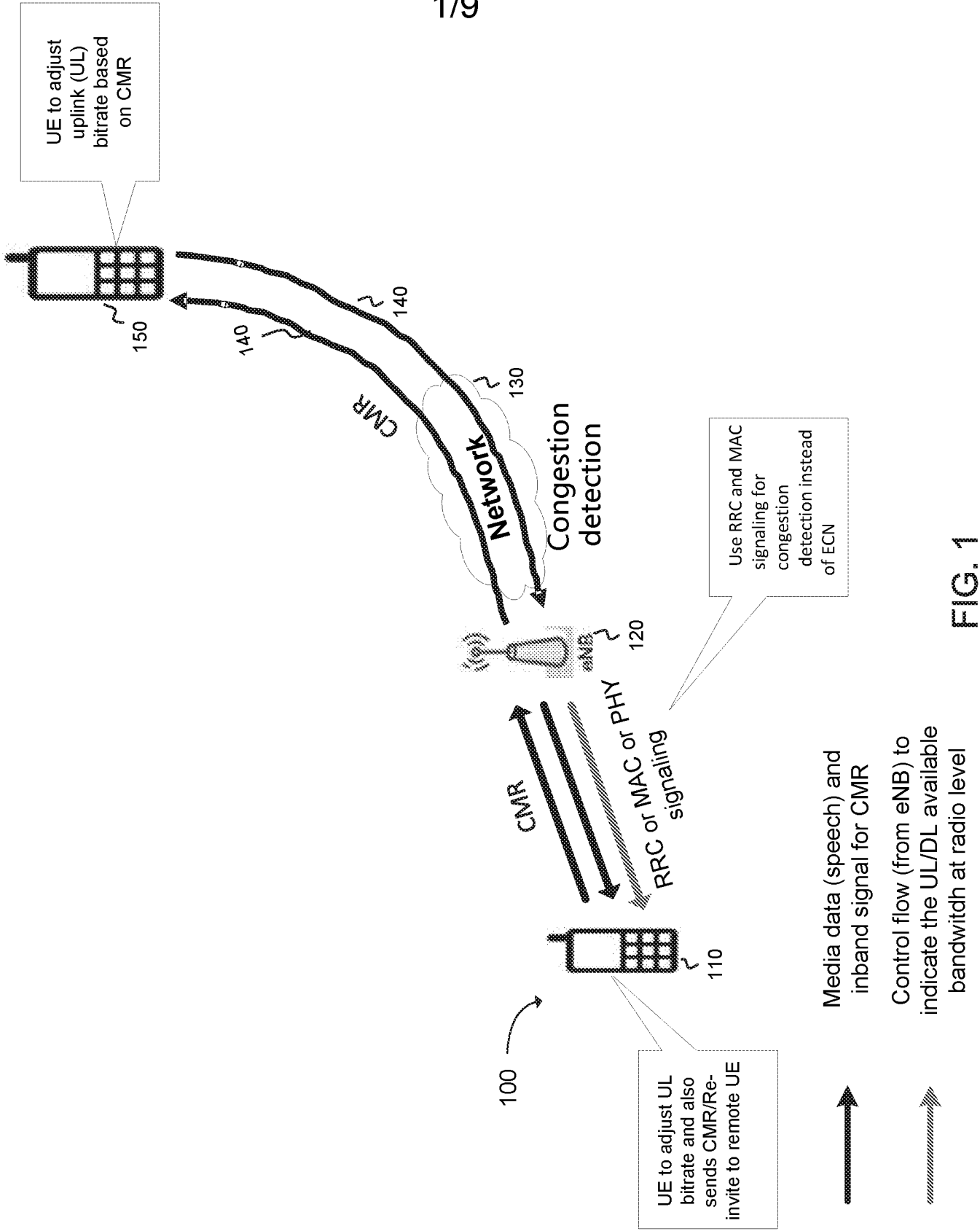


FIG. 1

2/9

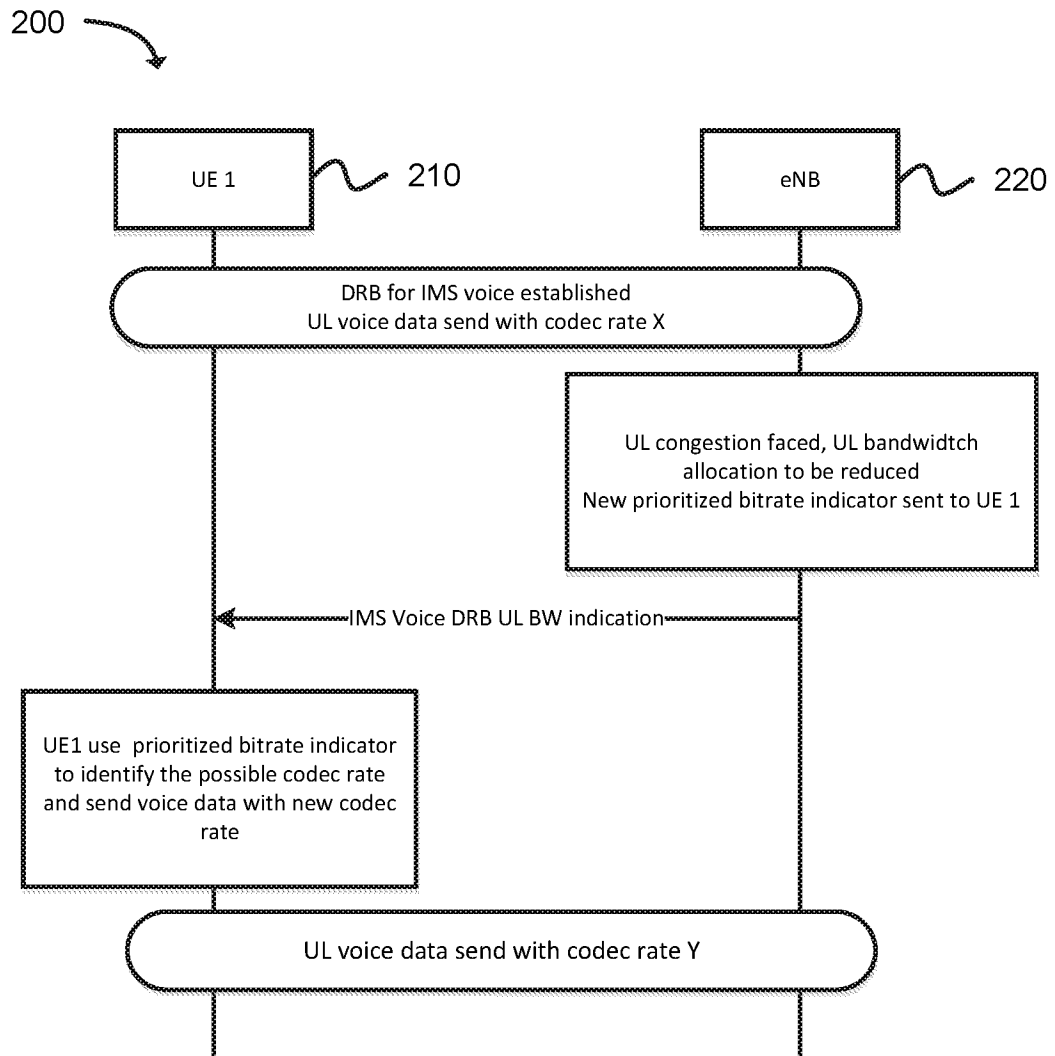


FIG. 2

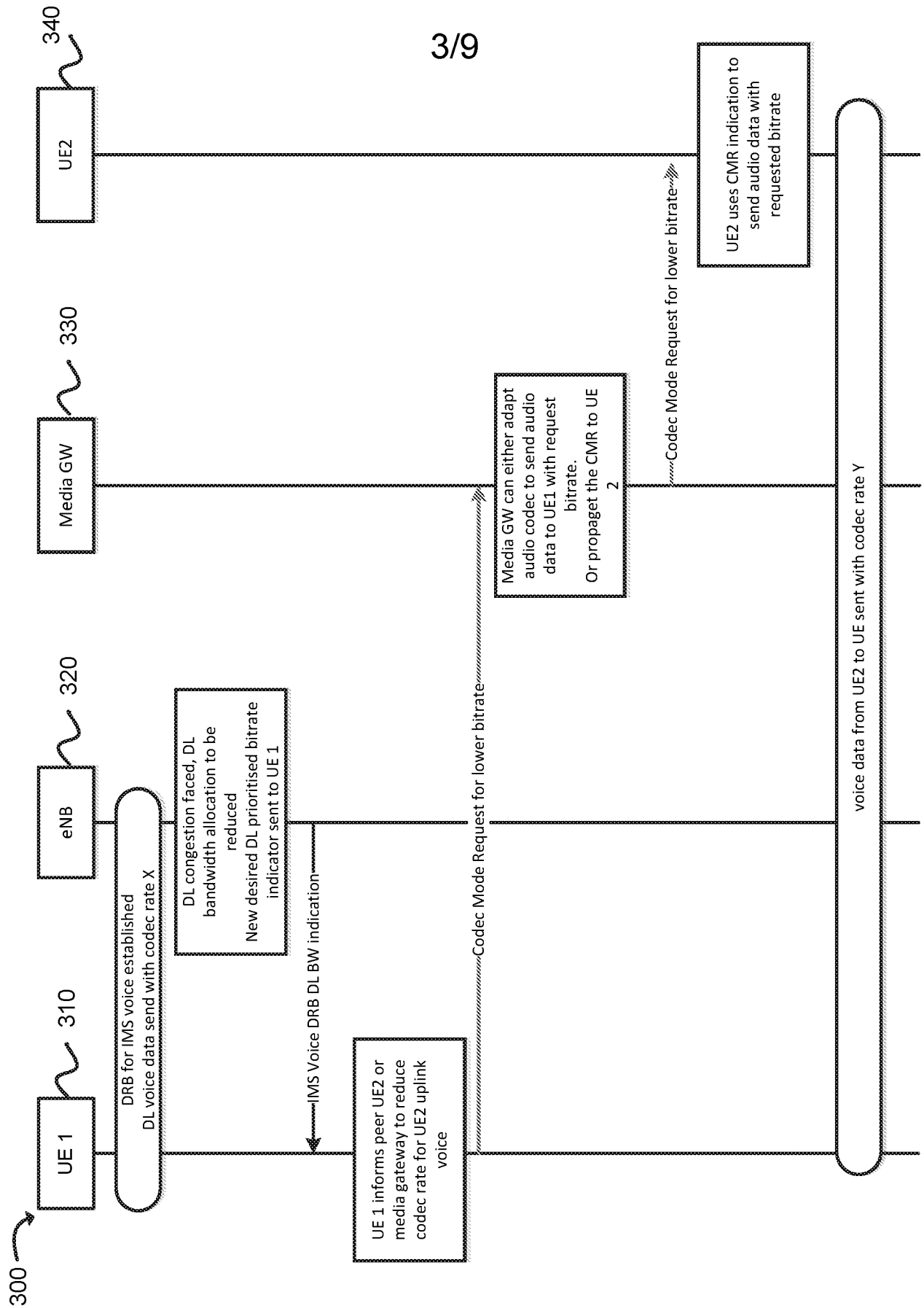


FIG. 3

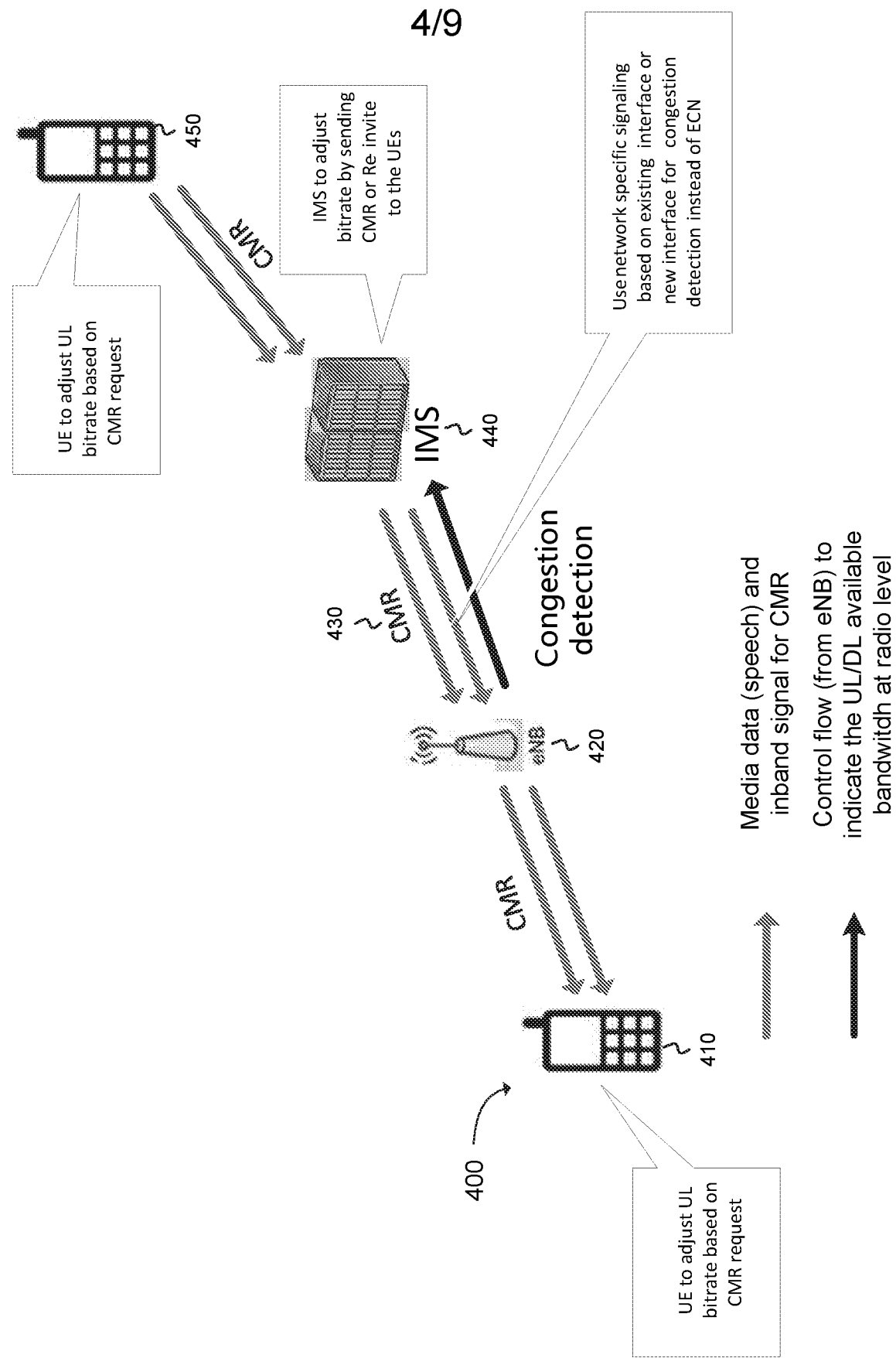


FIG. 4

5/9

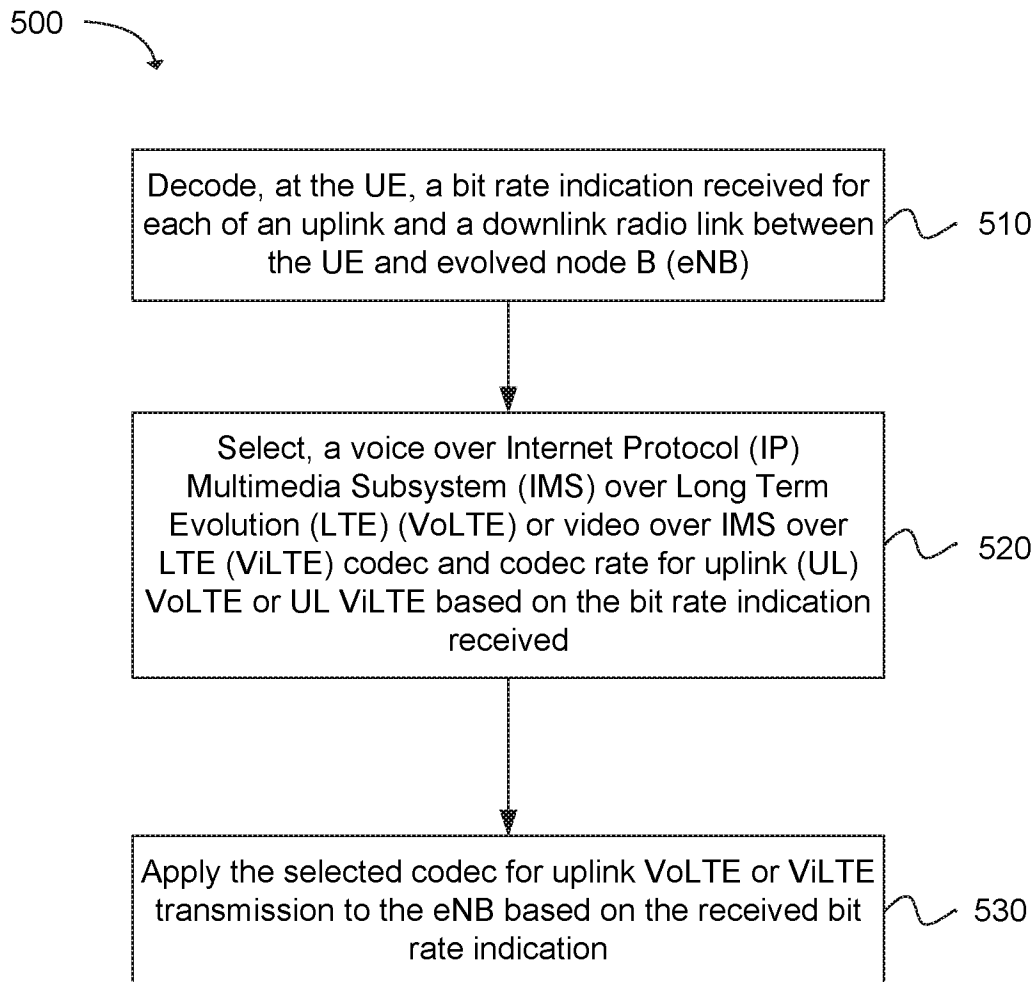


FIG. 5

6/9

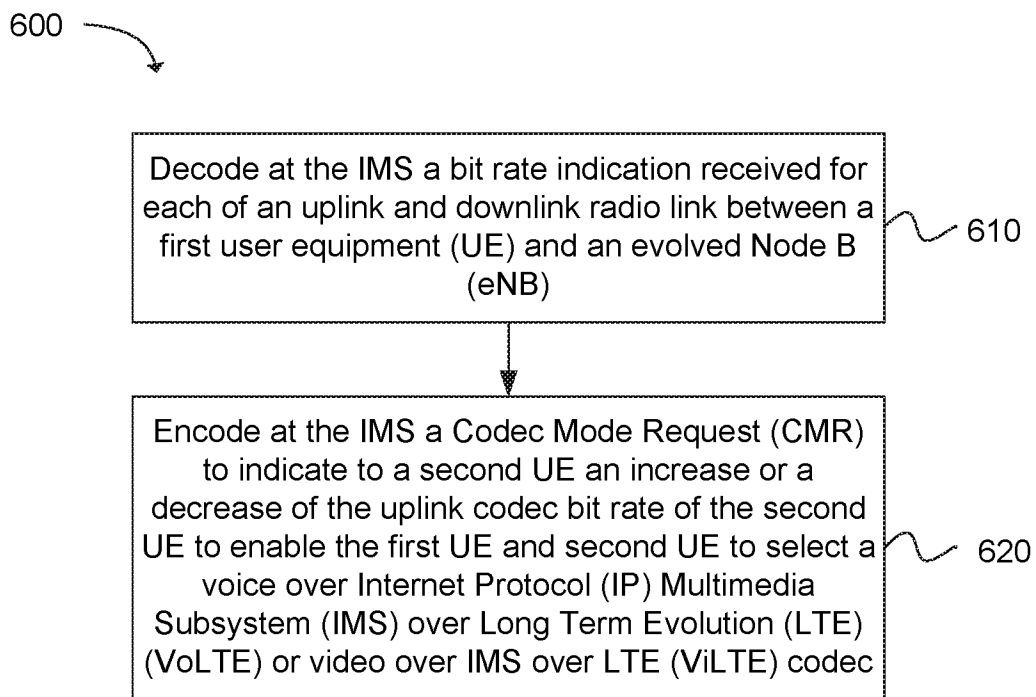


FIG. 6

7/9

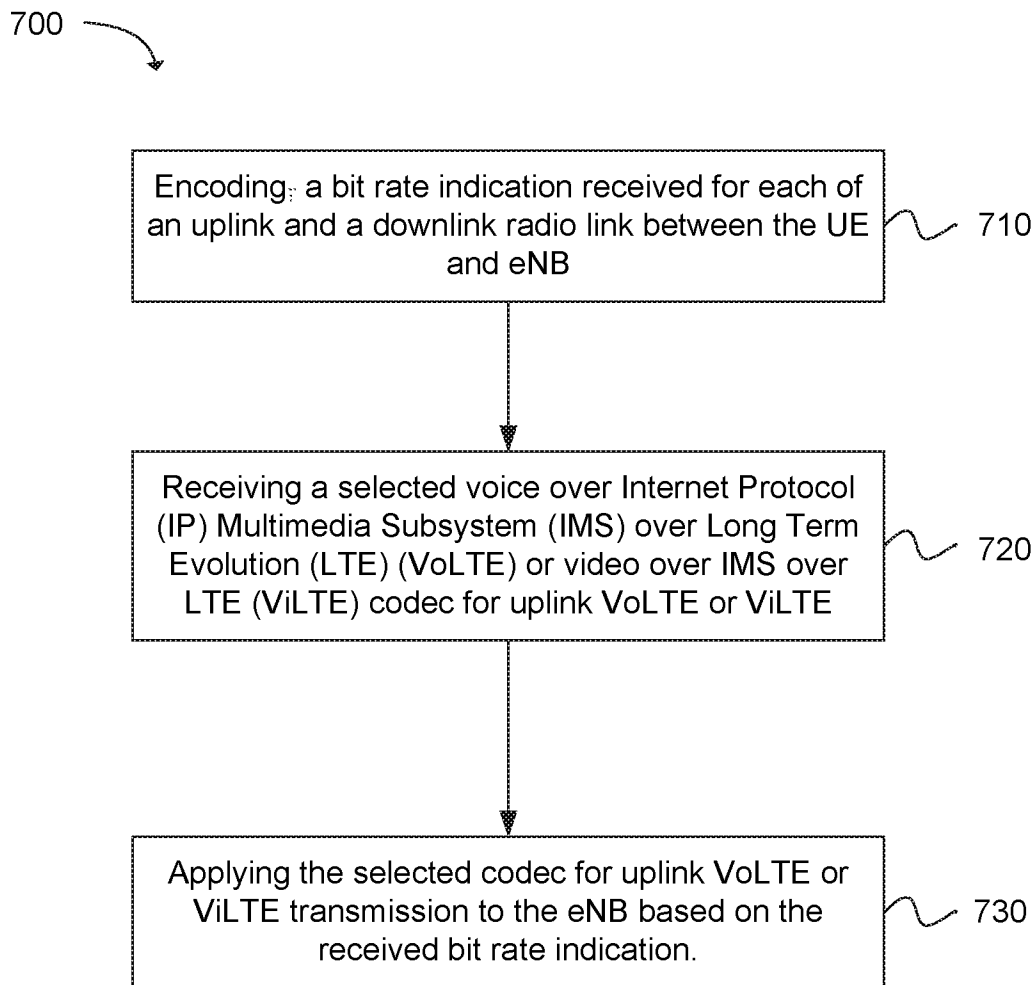


FIG. 7

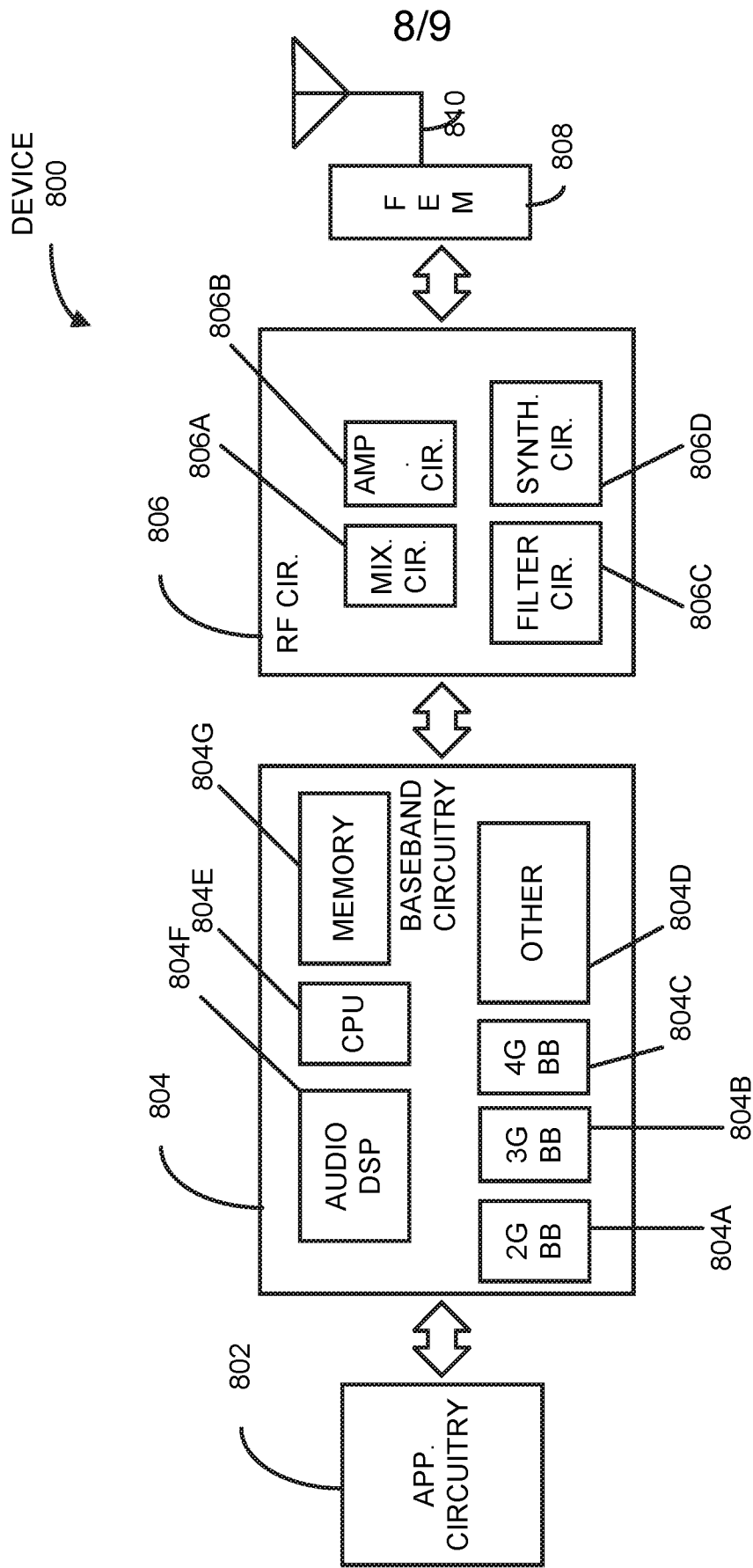


FIG. 8

9/9

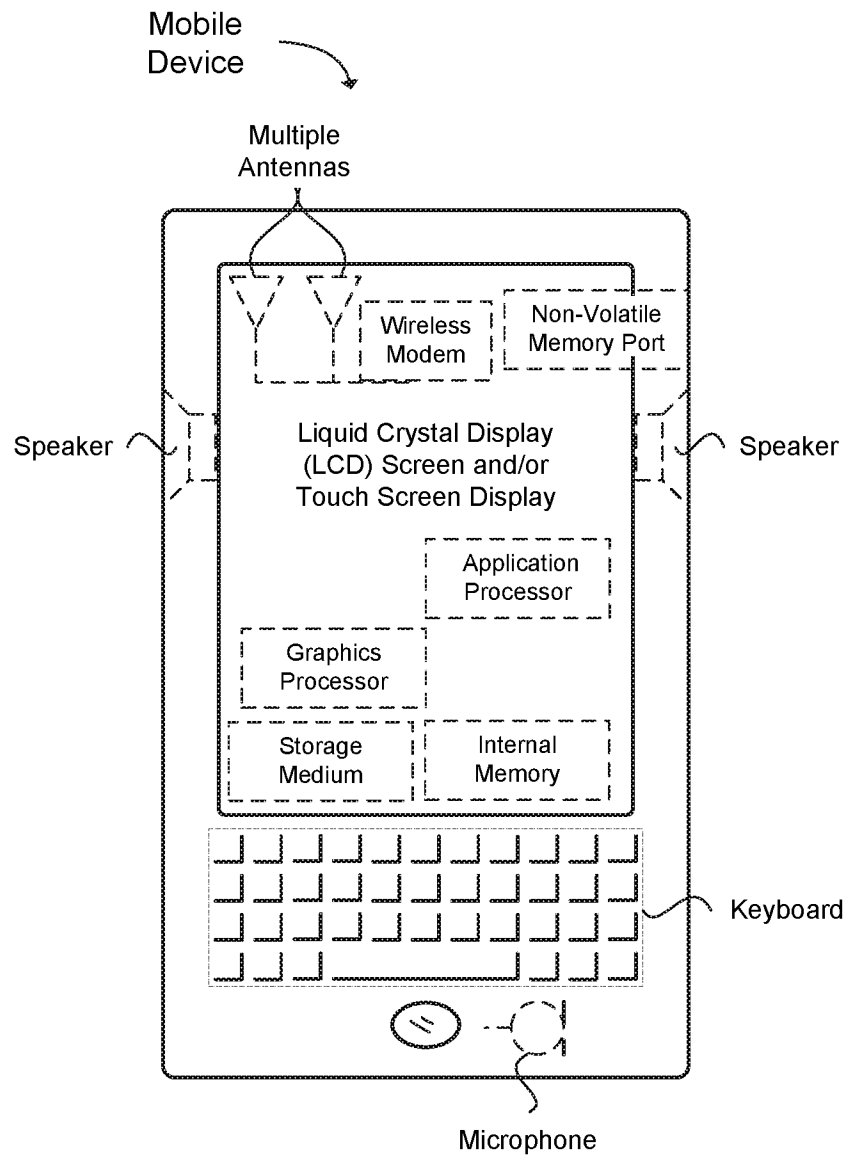


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/023651A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L1/00
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04L

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010/172332 A1 (RAO ANIL M [US]) 8 July 2010 (2010-07-08) paragraph [0021] - paragraph [0033] ----- -/--	1-22



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

13 June 2017

Date of mailing of the international search report

23/06/2017

Name and mailing address of the ISA/

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Authorized officer

Stolte, Norbert

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2017/023651

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	"3rd Generation Partnership Project; Technical Specification Group <TSG name>; Codec for Enhanced Voice Services (EVS); Interface to Iu, Uu, Nb and Mb (Release 13)", 3GPP DRAFT; 26.454-010, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , 29 January 2016 (2016-01-29), XP051073768, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_sa/WG4_COD EC/TSGS4_87/Docs/ [retrieved on 2016-01-29] tables 6.2-3 section 7.2	1-22
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2017/023651

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