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(54) Title: UPLINK TRANSMITTER AND RECEIVER USING UE-SELECTED MODULATION AND CODING SCHEME

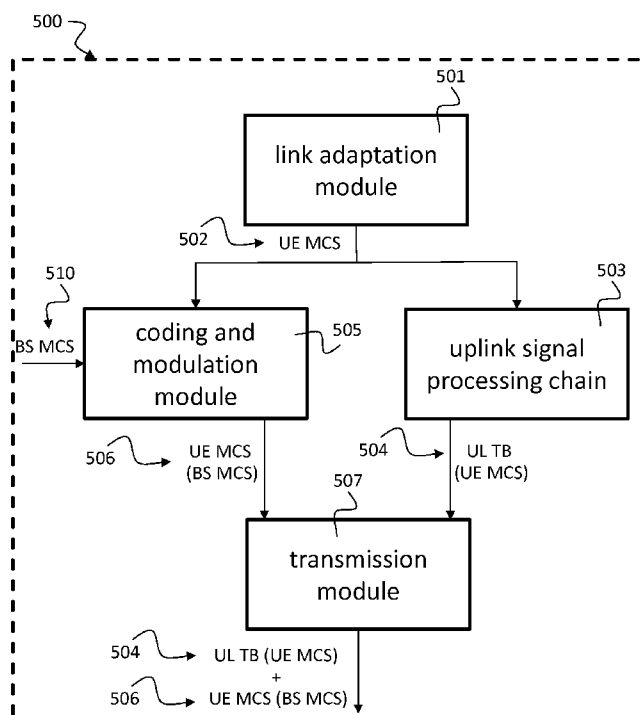


Fig. 5

(57) Abstract: The disclosure relates to an uplink transmitter (500) for a user equipment (UE) for communication to a base station (BS), the uplink transmitter (500) comprising: a link adaptation module (501), configured to select a UE modulation and coding scheme (MCS) (502) based on a target criterion; an uplink signal processing chain (503), configured to prepare and process an uplink transport block (504) according to the selected UE MCS (502); a coding and modulation module (505), configured to encode and modulate the selected UE MCS (502) according to a predetermined BS MCS (510); a transmission module (507), configured to transmit the processed uplink transport block (504) together with the modulated and encoded selected UE MCS (506) over an uplink radio communication channel. The disclosure further relates to an uplink receiver (1000) for a base station which demodulates and decodes the received uplink data symbols based on the decoded UE MCS value.



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UPLINK TRANSMITTER AND RECEIVER USING UE-SELECTED MODULATION AND CODING SCHEME

TECHNICAL FIELD

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The present disclosure relates to an uplink transmitter for a user equipment (UE) for communication to a base station (BS) and to an uplink receiver for a base station for communication to a user equipment. In particular, the present invention relates to link adaptation and associated transceiver scheme and signaling procedures at the UE in a baseline LTE (Long Term Evolution) system, particularly applicable to the 5G domains of V2X (Vehicle to Infrastructure) communication and Machine Type Communication (MTC) requiring low latency and high reliability.

BACKGROUND

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Link Adaptation is a key function in wireless networks aimed at choosing the most appropriate modulation order, code rate and other link parameters for a transmission to meet a target criterion e.g.: average Block error rate (BLER), Quality of Service (QoS) or Quality of Experience (QoE) metric. The general idea of link adaptation is to opportunistically adapt the link parameters according to the wireless channel in order to maximize the i) throughput in good channel conditions and ii) reliability in poor channel conditions. In cellular wireless systems like LTE, the link adaptation function is controlled entirely by the base station for both the uplink and downlink transmissions. This is in accordance with the centralized architecture of cellular networks in which the base station is the central coordinator possessing a global view of the network and directly or indirectly controls nearly all aspects of communication including scheduling, resource allocation, power control and link adaptation.

For the downlink, it is natural for the base station to control the link adaptation as it is the sole downlink transmitter and is responsible for multi-user scheduling in every downlink TTI. However, the base station also performs link adaptation for all scheduled users on the uplink. This has shown to be sub-optimal from a rate and reliability point of view due to imperfect and/or outdated Channel State Information (CSI). Note that this sub-optimality is not restricted to the uplink alone, but also applies to the downlink.

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Figure 1 shows the basic signalling and data transmission exchange for uplink communication in LTE 100.

In Step 1, the user equipment 120 sends a scheduling request 101 notifying the base station 110 that it wants to transmit on the uplink. In step 2, the base station 110 sends an Uplink Grant 102, with all scheduling information to the user equipment 120. In step 3, the user equipment 120 applies this scheduling information to the uplink transmission 103. In step 4, the base station 110 sends a feedback 104 for uplink transmission and a new grant to the user equipment 120 or alternatively a retransmission. Notice the delay between the MCS assignment at the base station 110 and the actual uplink transmission by the user equipment 120. In the best case (typically in FDD mode), this delay is 8 TTIs. In the worst case, in some TDD configurations, this delay can be minimum 13 TTIs.

Figure 2 shows a block diagram illustrating link adaptation in an LTE communication system 200.

The two blocks 220, 240 on the left represent the base station transceiver; the user equipment transceiver is on the right, represented by the blocks 210, 230.

The downlink (DL) transmitter 240 includes a coding and interleaving block 241, a symbol modulation block 242, a link adaptation block 243 and an OFDMA transmitter block 244.

The uplink (UL) receiver 220 includes an SC-FDMA receiver block 221, a channel estimation and equalization block 222 and a demodulation and decoding block 223.

The downlink (DL) receiver 230 includes an OFDM receiver block 231, a channel estimation and equalization block 232, an effective SNR calculation block 233 and a demodulation and decoding block 234. The uplink (UL) transmitter 210 includes an UL scheduler block 211, a coding and interleaving block 212, a symbol modulation block 213 and an SC-FDMA transmitter block 214.

The signalling flow for both uplink and downlink link adaptation is shown. DL pilots 253 are signalled from DL transmitter 240 to DL receiver 230. UL MCS 251 is signalled from DL transmitter 240 to UL transmitter 210. DL CSI with CQI, PMI and RI and DL ACK/NACK 252 are signalled from DL receiver 230 to DL transmitter 240. UL pilots 254 are signalled from UL transmitter 210 to UL receiver 220.

The link adaptation function (light shaded block 243) is centralized at the base station transmitter 240 and controls the link parameters for both uplink and downlink communication.

Figure 3 shows a time diagram 300 illustrating the effect of outdated feedback on link adaptation. As mentioned above, the state-of-the-art uplink link adaptation techniques in

LTE/LTE-A are suboptimal due to a delay between the MCS estimation at the base station and the actual uplink transmission at the user equipment. This results in over-estimation 301 or under-estimation 302 of the channel quality metric which is an input to the link adaptation and is described in Figure 3. Over-estimating 301 the channel quality results in more aggressive MCS selection (than the optimal), which increases retransmissions and reduces throughput. Under-estimation 302 results in more conservative MCS choice and a loss in throughput.

In legacy LTE systems, this sub-optimality and loss in throughput is generally tolerable, and partly compensated by HARQ retransmission or more conservative CQI-mappings by the UE (or MCS assignments by the bases station), as Quality of Service (QoS) requirements for latency and reliability are quite relaxed. However, newer use cases for 5G, particularly V2X and Machine Type Communication have stricter latency and reliability requirements: an ongoing 3GPP V2X standardization study mandates a maximum latency of 100ms with a maximum relative velocity of 280 km/h, a service frequency of 10 Hz and typical message sizes of 50-400 bytes. Another (future) use-case for V2V pre-crash sensing mandates a maximum latency of 20ms. While the first target of 100ms may be achievable with current State-of-the-art LTE solutions, the latter is extremely challenging and requires nearly 100% packet transmission reliability from Physical to IP layers. Current state-of-the-art LTE algorithms and solutions cannot satisfy this requirement. Achieving close to 100% transmission reliability for a particular message necessitates eliminating retransmissions at the physical layer i.e. achieving "single-shot" transmissions.

A further illustration of the impact of outdated Channel Quality Information (CQI) on the latency at the Physical layer is shown in the diagram 400 of Figure 4. LTE TDD mode is chosen because 1) the latencies are higher due to the time-multiplexing of uplink and downlink subframes and 2) uplink/downlink channel reciprocity is well-maintained after transceiver calibrations at both communicating nodes.

As seen in Figure 4, a single retransmission increases the latency to 20ms (26ms, if the scheduling request from user equipment is included (see Figure 1). In Figure 4, a best-case delay of 5 ms is assumed between MCS determination at the base station and actual uplink transmission. This is very optimistic because uplink CSI is based upon uplink wideband pilots (Sounding Reference Signals - SRS) which are time-multiplexed between all UEs in a cell; thus in any subframe only one user equipment can transmit the SRS. Therefore, in a cell with several users, the average "age" of the Uplink CSI from a particular user will be higher than the best case. This "CQI aging" directly affects link

adaptation performance, in particular in fast time-varying wireless channels and it is particularly severe on the uplink due to additional delays inherent in the frame structure.

SUMMARY

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It is the object of the invention to provide optimal link adaptation techniques with respect to throughput and delay for a communication between a user equipment and a base station, in particular according to LTE or LTE-A.

10 This object is achieved by the features of the independent claims. Further implementation forms are apparent from the dependent claims, the description and the figures.

A basic idea of the invention is to apply novel user-equipment centric link adaptation scheme in a cellular wireless system, including transmitter processing at UE, receiver
15 processing at base station and associated signaling to control the disclosed link adaptation scheme. The user equipment centric link adaptation scheme includes the following components: A modified uplink transmitter design at the user equipment, including resource mapping and transmit processing for signalling the UE-selected Modulation and Coding Scheme (MCS) along with the data; a modified uplink receiver
20 design at the base station, including receive processing that works in conjunction with the modified uplink transmitter; and signalling methods for activating/de-activating the new scheme or to control the dynamic range of the UE centric link adaptation. Using this novel user-equipment centric link adaptation scheme enables low latency and high reliability for the communication initiated by the user equipment.

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This disclosure presents a novel link adaptation and transceiver scheme at the user equipment in a cellular system and signalling methods to enable and control this scheme. The theoretical idea behind that concept can be explained as described in the following sections.

30

Link adaptation in both uplink and downlink of a cellular wireless system relies on accurate and up-to-date Channel State Information (CSI) for optimum performance. In practice, this is never realized due to feedback delays inherent in the frame structure of any communication standard, half-duplex operation of commercial radios and
35 measurement and reporting imperfections in practical network nodes. The goal of link adaptation is to maximize link performance (with respect to some pre-defined target criterion) in the presence of imperfect Channel State Information (CSI). The disclosure

addresses this goal by introducing a novel signalling scheme and method for uplink link adaptation at the user equipment of a wireless system, with the goal of mitigating the effects of imperfect and/or outdated CSI, thereby maximizing the throughput, in particular high layer throughput, (by minimizing retransmissions) and hence improving uplink performance.

The disclosed link adaptation scheme is most suitable for TDD systems as channel reciprocity is generally maintained between uplink and downlink, in particular due to the same frequency band of operation. This is important because the idea is that the user equipment uses the downlink CSI as one of the reference inputs for uplink link adaptation.

The disclosed link adaptation scheme is most beneficial in fast time-varying channels where the coherence time is on the order of a few TTIs. If the channel is slow varying or mostly static, the signalling overhead of the proposed scheme outweighs the benefits. An intuitive understanding can be gained from Figure 3 described above where variations in the effective SINR reflect variations in the wideband channel quality and the impact on the link adaptation performance depends very much on these variations as well as the duration τ . Here τ is the difference between the time of MCS estimation at the base station and the time of the uplink transmission at the UE. Hence, signalling mechanisms between the base station and user equipment are disclosed for enabling/disabling and controlling this scheme depending on the dynamic channel conditions (channel or link aware signalling).

The disclosed link adaptation scheme provides a cross-layer solution to link adaptation at the user equipment and comprises three main parts: The first part is Transmitter baseband processing at the user equipment, consisting of a new link adaptation module which selects an appropriate Modulation and Coding Scheme (MCS) and a modified transmitter which encodes and transmits the aforementioned MCS in a pre-determined fashion, in-band along with the data, after applying this MCS to the data itself. The second part is Receiver baseband processing at the base station, consisting of first decoding the MCS sent by the user equipment from pre-determined locations in the time-frequency resource grid, and subsequently decoding the data using the decoded MCS value. The third part is Control signalling of the above scheme by the base station.

In order to describe the invention in detail, the following terms, abbreviations and notations will be used:

	BS:	Base Station, eNodeB
	UE:	User Equipment, e.g. a mobile device or a machine type communication device
	V2X:	Vehicle to Infrastructure
5	5G:	5 th generation according to 3GPP standardization
	LTE:	Long Term Evolution
	MTC:	Machine Type Communication
	BLER:	Block Error Rate
	QoS:	Quality of Service
10	QoE:	Quality of Experience
	FDD:	Frequency Division Duplex
	TDD:	Time Division Duplex
	TTI:	Transmission Time Interval
	MCS:	Modulation and Coding Scheme or Set
15	CSI:	Channel State Information
	UL:	Uplink
	DL:	Downlink
	CQI:	Channel Quality Information
	IP:	Internet Protocol
20	DMRS:	Demodulation Reference Signal
	MAC:	Media Access Control
	LA:	Link Adaptation
	TB:	Transport Block
	RM:	Rate Matcher
25	DFT:	Discrete Fourier Transform
	FFT:	Fast Fourier Transform
	PUSCH:	Physical Uplink Shared Channel
	PDCCH:	Physical Downlink Control Channel
	ULSCH:	Uplink Shared Channel
30	CRC:	Cyclic Redundancy Check
	ACK:	Acknowledgement
	NACK:	Non- Acknowledgement
	HARQ:	Hybrid Automatic Repeat Request
	PMI:	Precoding Matrix Indicator
35	RI:	Rank Indicator
	SI:	System Information
	DCI:	Downlink Control Information

M2M: Machine to Machine
LTE-M: Machine to Machine version of LTE
D2D: Device to Device
RF: Radio Frequency

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According to a first aspect, the invention relates to an uplink transmitter for a user equipment (UE) for communication to a base station (BS), the uplink transmitter comprising: a link adaptation module, configured to select a UE modulation and coding scheme (MCS) based on a target criterion; an uplink signal processing chain, configured to prepare and process an uplink transport block according to the selected UE MCS; a coding and modulation module, configured to encode and modulate the selected UE MCS according to a predetermined BS MCS; a transmission module, configured to transmit the processed uplink transport block together with the modulated and encoded selected UE MCS over an uplink radio communication channel.

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The uplink transmitter can generate its own MCS that has a higher quality than the outdated and possibly suboptimal MCS assigned by the base station. Therefore, the advantage of high throughput and low delay can be achieved due to the optimal link adaptation. The predetermined BS MCS may be a modulation and coding scheme that is predefined by the base station. However, it can also be predefined by another device, for example a network management node, or by the UE itself or by factory settings.

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In a first possible implementation form of the uplink transmitter according to the first aspect, the target criterion is based on at least one of the following: an average Block Error Rate (BLER), a Quality of Service (QoS) metric, a Quality of Experience (QoE) metric, in particular based on a BLER of 10 percent or 1 percent.

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This provides the advantage that the uplink transmitter is flexible in providing the UE MCS; different target metrics can be used for computing this UE MCS value.

30

In a second possible implementation form of the uplink transmitter according to the first aspect as such or according to the first implementation form of the first aspect, the target criterion is based on at least one of the following: at least a subset of a plurality of downlink reference signals, a resource block allocation assigned by the BS, an average BLER over a predetermined or dynamically varying window, a pending data in an uplink buffer and an instantaneous channel condition, in particular a Carrier Frequency Offset

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(CFO), a reference signal received power (RSRP) or a signal-to-interference-plus noise ratio (SINR).

5 This provides the advantage that different methods may be used to compute the target metric. This provides flexibility at the UE. The target metric which is as accurate as possible in the specific situation can be applied.

10 In a third possible implementation form of the uplink transmitter according to the first aspect as such or according to any one of the preceding implementation forms of the first aspect, the link adaptation module is configured to select the UE MCS responsive to a reception of an uplink grant from the BS. Or, in an alternative, responsive to a periodically scheduled grant.

15 This provides the advantage that selecting the UE MCS can be synchronized with the base station.

20 In a fourth possible implementation form of the uplink transmitter according to the first aspect as such or according to any one of the preceding implementation forms of the first aspect, the coding and modulation module is configured to modulate the encoded selected UE MCS, to generate UE MCS symbols which are then mapped to a time-frequency resource grid according to the predetermined BS MCS.

25 This provides the advantage that the UE MCS symbols can be transmitted by using the same mechanism as used for transporting user data or control data. The uplink transmitter can be easily applied in an LTE communication system, only few blocks have to be changed.

30 In a fifth possible implementation form of the uplink transmitter according to the fourth implementation form of the first aspect, the coding and modulation module is configured to allocate the UE MCS symbols at predetermined positions on the resource grid, in particular at positions predetermined by the BS, in particular at first symbol positions of the resource grid.

35 This provides the advantage that a fast and efficient decoding of the UE MCS symbols can be performed due to their known positions in the grid. When symbol positions at the start of a frame are used, decoding can be accelerated because the first symbols to be

decoded are the UE MCS symbols that are successively used for decoding the remaining symbols of the frame.

5 In a sixth possible implementation form of the uplink transmitter according to the fourth or the fifth implementation form of the first aspect, the uplink signal processing chain comprises a media access control (MAC) module, configured to prepare the uplink transport block (UL TB) based on the selected UE MCS and a given resource block allocation, in particular a resource block allocation given by the BS.

10 This provides the advantage that the MAC module can prepare the UL TB based on the selected UE MCS and does not have to use an outdated and possibly suboptimal MCS from the base station. Hence delay in providing the UL TB can be reduced. When using the given resource block allocation, the BS receiver knows the positions of the respective resource blocks and can quickly decode a received frame or subframe.

15 In a seventh possible implementation form of the uplink transmitter according to the sixth implementation form of the first aspect, the uplink signal processing chain comprises a rate matcher, a data and control multiplexer, a channel interleaver and a modulator which are configured to apply the selected UE MCS to the prepared uplink transport block to
20 generate uplink data symbols onto the time-frequency resource grid.

This provides the advantage that the same processing blocks that are used for standard LTE transmission can also be used for transmission using the disclosed link adaptation scheme when instead of the MCS received from the base station the new UE MCS
25 selected by the UE is applied for processing. Only a minimal change in these blocks may be required. That means that the uplink transmitter is in conformance with the LTE standard.

30 In an eighth possible implementation form of the uplink transmitter according to the seventh implementation form of the first aspect, the uplink signal processing chain is configured to multiplex the UE MCS symbols together with the uplink data symbols on the time-frequency resource grid according to a predetermined multiplexing scheme, in particular a multiplexing scheme predetermined by the BS.

35 This provides the advantage that the UE MCS symbols can be quickly demultiplexed, demodulated and decoded by the base station which knows the predetermined multiplexing

scheme and this decoded MCS value can be further used for decoding the uplink data symbols.

5 In a ninth possible implementation form of the uplink transmitter according to the eighth implementation form of the first aspect, the uplink transmitter is configured to activate and/or deactivate the link adaptation module; and/or the uplink signal processing chain, in particular based on downlink information and signaling.

10 This provides the advantage that the link adaptation scheme can easily be enabled or disabled. When the link adaptation module is disabled, the uplink transmitter is compatible to a conventional base station, when the link adaptation module is enabled, the uplink transmitter can interact with a base station that has also implemented such link adaptation scheme.

15 In case of a deactivation of the link adaptation module and/or the uplink signal processing chain, the transmission module is configured to send the transport block encoded by MCS assigned by the base station.

20 According to a second aspect, the invention relates to an uplink receiver for a base station (BS) for communication to a user equipment (UE), the uplink receiver comprising: a reception module, configured to receive a radio signal comprising UE modulation and coding scheme (MCS) symbols and uplink data symbols; a demodulation and decoding module, configured to demodulate and decode the UE MCS symbols according to a predetermined BS MCS to provide a decoded UE MCS value; and an uplink signal
25 processing chain, configured to demodulate and decode the uplink data symbols based on the decoded UE MCS value.

Due to the UE selecting the modulation and coding scheme, the duration τ between MCS selection and UL transmission to the base station can be reduced. The uplink receiver can
30 apply the MCS generated by the uplink transmitter which has a higher quality than the outdated and possibly suboptimal MCS assigned earlier by the base station. Therefore, the advantage of high throughput and low delay can be achieved due to the optimal link adaptation. The predetermined BS MCS may be a modulation and coding scheme that is predefined by the base station. However, it can also be predefined by another device, for
35 example a network management node, or by the UE itself or by factory settings.

In a first possible implementation form of the uplink receiver according to the second aspect, the uplink signal processing chain is configured to de-multiplex the UE MCS symbols from the uplink data symbols according to a predetermined de-multiplexing scheme, in particular a de-multiplexing scheme predetermined by the BS.

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This provides the advantage that the UE MCS symbols can be quickly detected by the uplink receiver in the base station which knows the predetermined de-multiplexing scheme and the de-multiplexed UE MCS can be used for decoding the uplink data symbols. The predetermined de-multiplexing scheme in the uplink receiver at the base station corresponds to the predetermined multiplexing scheme in the uplink transmitter at the UE.

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In a second possible implementation form of the uplink receiver according to the second aspect as such or according to the first implementation form of the second aspect, the uplink signal processing chain comprises a channel de-interleaver and a data and control de-multiplexer which are configured to separate the uplink data symbols into data bits and control bits according to the decoded UE MCS value, wherein the control bits can comprise at least one of the following: CQI bits, PMI bits, ACK bits, NACK bits, RI bits.

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This provides the advantage that the same processing blocks that are used for standard LTE reception can also be used for reception using the disclosed link adaptation scheme when instead of the MCS assigned by the base station the new decoded UE MCS as selected by the UE is applied for processing. Only a minimal change in these blocks may be required. That means that the uplink receiver is in conformance with the LTE standard.

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In a third possible implementation form of the uplink receiver according to the second aspect as such or according to any one of the preceding implementation forms of the second aspect, the uplink signal processing chain comprises a rate de-matcher, configured to output a rate de-matched coded bit-stream according to the decoded UE MCS value.

30

This provides the advantage that the rate de-matched coded bit-stream output according to the UE MCS value benefits from improved rate adaptation arising from the utilization of the UE MCS value which is more closely adapted to the channel than the eNB assigned MCS due to the reduced delay between MCS assignment and uplink transmission in the case of UE-assigned MCS.

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According to a third aspect, the invention relates to a method for signaling a link adaptation control to an uplink transmitter of a user equipment, in particular an uplink transmitter according to the first aspect as such or according to any one of the preceding implementation forms of the first aspect, the method comprising: transmitting a message from a base station (BS) to the user equipment (UE), the message comprising information indicating an enabling or disabling of a UE modulation and coding scheme (MCS) selection; and enabling or disabling the UE MCS selection in a link adaptation module of an uplink transmitter of the UE according to the information received from the BS.

When applying such a method high throughput and low delay can be achieved by UE selection of modulation and coding scheme for uplink transmissions. The uplink receiver can apply the MCS generated by the uplink transmitter which has a higher quality than the outdated and possibly suboptimal MCS received with some delay from the base station. Therefore, by using this method, the advantage of high throughput and/or low delay can be achieved due to the optimal link adaptation.

In a first possible implementation form of the method according to the third aspect, the method comprises: transmitting the message by one of semi-static signaling (also known as semi persistent scheduling) via RRC messages or on-demand signaling via downlink control signals and/or broadcast signals via system information blocks; controlling a dynamic range of the link adaptation module; and exchanging calibration coefficients between the BS and the UE, the calibration coefficients indicating a channel reciprocity between downlink and uplink transmission.

This provides the advantage that flexible signaling can be applied depending on the requirements. By exchanging calibration coefficients, the accuracy of channel estimation and data processing can be further improved.

According to a fourth aspect, the invention relates to a link adaptation and transmission method for a user equipment, comprising: Determining the most appropriate MCS for the next uplink transmission based on some or all of the following: a subset or whole of downlink reference signals (cell and/or UE- specific), assigned resource block allocation by the base station, average uplink BLER over a pre-defined or dynamically varying window, instantaneous channel condition (estimated CFO, RSRP, SINR etc.), pending data in uplink buffer; Encoding and Modulating the selected MCS value, using a pre-defined Modulation and Coding Scheme, to generate the 'MCS symbols'; Preparing a Transport Block according to the UE-selected MCS and the RB allocation assigned by the

base station; Applying the UL-SCH processing chain, as described below with respect to Figure 7; and Applying the PUSCH processing chain, as described below with respect to Figure 9.

- 5 When applying such a method, high throughput and/or low delay can be achieved because the most appropriate MCS based on the latest available channel state information for next Uplink transmission is selected and applied by the UE.

10 According to a fifth aspect, the invention relates to a link adaptation and reception method for a base station, comprising: Demultiplexing the MCS symbols from the pre-assigned positions in the equalized time-frequency resource grid; Demodulating the MCS symbols, De-interleaving the coded MCS bits from the demodulated MCS symbols; Performing channel decoding to obtain the MCS value; Using the decoded MCS value to decode the rest of the PUSCH data as described below with respect to Figure 11.

15 Using this novel user-equipment centric link adaptation and reception method enables low latency and/or high reliability for the communication initiated by the user equipment.

20 According to a sixth aspect, the invention relates to a signaling method for enabling/disabling/controlling the link adaptation and transmitter/receiver methods at the user equipment and the base station according to the fourth and fifth aspects, comprising: Semi-static signaling via RRC messages or on-demand signaling with downlink control signals (DCI) by the base station for enabling or disabling the proposed link adaptation scheme at the user equipment; Controlling of dynamic range of UE-centric link adaptation;
25 Exchanging calibration coefficients between base station and user equipment via said signaling to ensure channel reciprocity between downlink and uplink.

30 When using UE-centric link adaptation according to this method link performance can be maximized with respect to some pre-defined target criterion in the presence of imperfect Channel State Information (CSI).

BRIEF DESCRIPTION OF THE DRAWINGS

35 Further embodiments of the invention will be described with respect to the following figures, in which:

Figure 1 shows a message sequence diagram illustrating an uplink scheduling scheme in LTE 100;

5 Figure 2 shows a block diagram illustrating link adaptation in a communication system 200;

Figure 3 shows a time diagram 300 illustrating the effect of outdated feedback on link adaptation;

10 Figure 4 shows a time diagram 400 illustrating the impact of outdated CQI on Uplink link adaptation and latency;

15 Figure 5 shows a block diagram illustrating an uplink transmitter 500 for a user equipment according to an implementation form;

Figure 6 shows a block diagram illustrating an LTE uplink transmitter 600 for a user equipment according to an implementation form;

20 Figure 7 shows a schematic diagram illustrating an exemplary uplink signal processing 700 in the LTE uplink transmitter 600 according to an implementation form;

25 Figure 8 shows an exemplary realization of a time-frequency resource grid 800 after channel interleaving in the LTE uplink transmitter 600 according to an implementation form;

Figure 9 shows a block diagram illustrating an exemplary PUSCH processing chain 900 in the LTE uplink transmitter 600 according to an implementation form;

30 Figure 10 shows a block diagram illustrating an uplink receiver 1000 for a base station according to an implementation form;

Figure 11 shows a block diagram illustrating an LTE uplink receiver 1100 for a base station according to an implementation form;

35 Figure 12 shows a schematic diagram illustrating a signaling message diagram 1200 for activating or deactivating the UE link adaptation scheme according to an implementation form;

Figure 13 shows a downlink control information (DCI) table 1300 according to an implementation form illustrating exemplary contents of DCI Format 0;

- 5 Figure 14 shows a performance diagram 1400 illustrating an exemplary target benefit of a link adaptation scheme according to the disclosure;

Figure 15 shows a performance diagram 1500 illustrating an exemplary MCS signaling overhead versus the number of allocated resource blocks;

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Figure 16 shows a view on a vehicle to infrastructure (V2X) communication system 1600 applying a link adaptation scheme according to the disclosure;

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Figure 17 shows a block diagram illustrating a communication system 1700 according to an implementation form in which hardware imperfections affect reciprocity; and

Figure 18 shows a schematic diagram illustrating a method 1800 for signaling link adaptation control to an uplink transmitter of a user equipment according to an implementation form.

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DETAILED DESCRIPTION OF THE EMBODIMENTS

In the following detailed description, reference is made to the accompanying drawings, which form a part thereof, and in which is shown by way of illustration specific aspects in which the disclosure may be practiced. It is understood that other aspects may be utilized and structural or logical changes may be made without departing from the scope of the present disclosure. The following detailed description, therefore, is not to be taken in a limiting sense, and the scope of the present disclosure is defined by the appended claims.

30 It is understood that comments made in connection with a described method may also hold true for a corresponding device or system configured to perform the method and vice versa. For example, if a specific method step is described, a corresponding device may include a unit to perform the described method step, even if such unit is not explicitly described or illustrated in the figures. Further, it is understood that the features of the various exemplary aspects described herein may be combined with each other, unless
35 specifically noted otherwise.

Figure 5 shows a block diagram illustrating an uplink transmitter 500 for a user equipment (UE) for communication to a base station (BS) according to an implementation form. The uplink transmitter 500 includes a link adaptation module 501, an uplink signal processing chain 503, a coding and modulation module 505 and a transmission module 507.

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The link adaptation module 501 is configured to select a UE modulation and coding scheme (MCS, from a predefined set of MCS values) 502 based on a target criterion. The uplink signal processing chain 503 is configured to prepare and process an uplink transport block 504 according to the selected UE MCS 502. The coding and modulation module 505 is configured to encode and modulate the selected UE MCS 502 according to a predetermined BS MCS 510. The transmission module 507 is configured to transmit the processed uplink transport block 504 together with the modulated and encoded selected UE MCS 506 over an uplink radio communication channel.

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15 The predetermined BS MCS 510 is a specific modulation and coding scheme that may be predetermined or predefined by the base station or by any other network device or that may be initially predefined, e.g. from a manufacturing process.

20 The target criterion may be based on an average Block Error Rate (BLER), a Quality of Service (QoS) metric or a Quality of Experience (QoE) metric. The average BLER may have an exemplary value of 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 15, 20, 25, 30, 35, 40, 50 percent or any other percentage value, preferably a value of 10 percent or 1 percent.

25 The target criterion may be based on at least a subset of a plurality of downlink reference signals, a resource block allocation assigned by the BS, an average BLER over a predetermined or dynamically varying window, a pending data in an uplink buffer and/or an instantaneous channel condition, for example a Carrier Frequency Offset (CFO), a reference signal received power (RSRP) or a signal-to-interference-plus noise ratio (SINR).

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The link adaptation module 501 may select the UE MCS 502 responsive to a reception of an uplink grant from the BS. The coding and modulation module 505 may modulate the encoded selected UE MCS to generate UE MCS symbols onto a time-frequency resource grid, e.g. a resource grid 800 as described below with respect to Figure 8, according to the predetermined BS MCS 510, e.g. as described below with respect to Figure 6. The coding and modulation module 505 may allocate the UE MCS symbols at predetermined positions on the resource grid, in particular at positions predetermined by the BS, in

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particular at first symbol positions MCS of the resource grid as shown in Figure 8. The predetermined positions of the MCS symbols may alter the existing positions of other Uplink Control information (if any) on the resource grid, but this will be known to both the BS and the UE.

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The uplink signal processing chain 503 may include a media access control (MAC) module, e.g. a MAC module 601 as described below with respect to Figure 6, configured to prepare the uplink transport block 504 based on the selected UE MCS 502 and a given resource block allocation, in particular a resource block allocation given by the BS.

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The uplink signal processing chain 503 may include a rate matcher, e.g. a rate matcher 605 as described below with respect to Figure 6, a data and control multiplexer, e.g. a multiplexer 607 as described below with respect to Figure 6, a channel interleaver and modulator, e.g. a interleaver and modulator device 609 as described below with respect to Figure 6 which are configured to apply the selected UE MCS 502 to the prepared uplink transport block 504 to generate uplink data symbols onto the time-frequency resource grid, e.g. uplink data symbols 604 as described below with respect to Figure 6.

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The uplink signal processing chain 503 may be configured to multiplex the UE MCS symbols together with the uplink data symbols on the time-frequency resource grid according to a predetermined multiplexing scheme, in particular a multiplexing scheme predetermined by the BS. Multiplexing 615 the UE MCS symbols 606 with the uplink data symbols 604 may be as described below with respect to Figure 6.

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The uplink transmitter 500 may be configured to activate and/or deactivate the link adaptation module 501; and/or the uplink signal processing chain 503. In case of a deactivation of the link adaptation module and/or the uplink signal processing chain, the transmission module may be configured to send the transport block encoded by the predefined MCS (only, and not the UE-MCS information).

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Figure 6 shows a block diagram illustrating an LTE uplink transmitter 600 for a user equipment according to an implementation form. The design of the uplink transmitter 600 incorporates and enables the novel link adaptation function in the user equipment. Figure 6 shows one realization of the general transmitter design 500 shown in Figure 5, under the assumption of LTE Uplink transmitter.

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The uplink transmitter 600 includes a link adaptation module 501, an uplink signal processing chain 503, a coding and modulation module 505 and a transmission module (not shown in Figure 6).

The link adaptation module 501 is configured to select a UE modulation and coding scheme (MCS), also denoted as "MCS Value" 502 based on a target criterion. The uplink signal processing chain 503 is configured to prepare and process an uplink transport block, abbreviated as TB 504 according to the selected UE MCS 502. The coding and modulation module 505 is configured to encode and modulate the selected UE MCS 502 according to a predetermined BS MCS. The transmission module (not shown in Figure 6) is configured to transmit the processed uplink transport block together with the modulated and encoded selected UE MCS over an uplink radio communication channel.

The predetermined BS MCS is a specific modulation and coding scheme that may be predetermined or predefined by the base station or by any other network device or that may be initially predefined, e.g. from a manufacturing process.

The target criterion may be based on an average Block Error Rate (BLER), a Quality of Service (QoS) metric or a Quality of Experience (QoE) metric as described above with respect to Figure 5. The target criterion may be based on at least a subset of a plurality of downlink reference signals, a resource block allocation assigned by the BS, an average BLER over a predetermined or dynamically varying window, a pending data in an uplink buffer and/or an instantaneous channel condition, for example a Carrier Frequency Offset (CFO), a reference signal received power (RSRP) or a signal-to-interference-plus noise ratio (SINR) as described above with respect to Figure 5.

The link adaptation module 501 may select the UE MCS 502 responsive to a reception of an uplink grant from the BS. The coding and modulation module 505 including a coding block 611 and a modulation block 613 may encode and modulate the selected UE MCS to generate UE MCS symbols 606 onto a time-frequency resource grid, e.g. a resource grid 800 as described below with respect to Figure 8, according to the predetermined BS MCS. The coding and modulation module 505 may allocate the UE MCS symbols 606 at predetermined positions on the resource grid, in particular at positions predetermined by the BS, in particular at first symbol positions MCS of the resource grid as shown in Figure 8. After the coding block 611 coded MCS symbols 602 are generated that may be provided to the data/control multiplexer and channel interleaving block 607 of the signal processing chain 503. In an alternate embodiment, the coding block may directly provide

the encoded bit-stream containing the UE MCS to the Channel Interleaving Block as shown in Figure 7.

The uplink signal processing chain 503 may include a media access control (MAC)

5 module 601, configured to prepare the uplink transport block 504 based on the selected UE MCS 502 generated by the link adaptation module 501 which may be part of the MAC module 601 and a given resource block allocation, in particular a resource block allocation given by the BS.

10 The uplink signal processing chain 503 may include a rate matcher 605, a data and control multiplexer 607, a channel interleaver and modulator 609 which may be configured to apply the selected UE MCS 502 to the prepared uplink transport block 504 to generate uplink data symbols 604 onto the time-frequency resource grid. The uplink signal processing chain 503 may include a Turbo encoding module for channel coding of the
15 uplink transport block 504 by a Turbo Code before passing it to the rate matcher 605 and successively to the data and control multiplexer and channel interleaver 607 and the modulator 609. The uplink data symbols 604 may be generated at the output of the modulator 609.

20 The uplink signal processing chain 503 may include a multiplexer 615 that may be configured to multiplex the UE MCS symbols 606 together with the uplink data symbols 604 on the time-frequency resource grid according to a predetermined multiplexing scheme, in particular a multiplexing scheme predetermined by the BS. In an alternate embodiment, the channel interleaver may receive the coded bitstream corresponding to
25 the UE MCS from the coding block and interleave it with rest of the PUSCH data and Control bits in such a manner as to generate an output bitstream that follows the order of pre-determined multiplexing scheme. The output bitstream is sent to the modulator which encodes the UE MCS bits using the pre-determined modulation order corresponding to the predetermined BS MCS and the rest of the bits according to the modulation order
30 specified by the UE MCS.

The uplink transmitter 500 may be configured to activate and/or deactivate the link adaptation module 501; and/or the coding and modulation block 505. In case of a deactivation of the link adaptation module 501 and/or the coding and modulation block
35 505, the transmission module may be configured to send the transport block encoded by the MCS assigned by the base station (and not the UE-MCS information).

After the multiplexer 615, the signal may pass a DFT 617, a DMRS multiplexer 619 that may include DMRS symbols to the signal, further a resource mapper 623, an IFFT block 625 and a half shift and cyclic prefix (CP) block 627 before reaching the transmission module.

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An exemplary functionality of the above described blocks is described in the following section.

The Link Adaptation (UE LA) entity 501 in the user equipment computes the optimum MCS value to use on the uplink channel, based on several inputs such as downlink reference symbols (pilots), resource assignment by the base station, amount and priority of pending data in its own uplink buffer, and so on.

When the user equipment receives an uplink grant from the base station, the UE LA entity 501 chooses the most appropriate MCS at either that instant, or at a later instant but before the scheduled uplink transmission.

As soon as the MCS is selected 502 by the UE LA entity 501, the UE MAC entity 601 prepares a MAC Transport Block (TB) 504 of the required size (based on chosen MCS 502 and the resource block allocation by the base station).

This MCS value 502 undergoes modulation and coding 505 to generate complex modulated symbols 606. Simultaneously, the chosen MCS 505 is informed to the Rate Matcher 605, Data/Control Multiplexer, Channel Interleaver 607 and the Modulation entities 609 in the uplink signal processing chain 503, along with an optional indication that the disclosed Link Adaptation scheme is activated (optional because the signaling of the chosen UE MCS to the aforementioned entities like the Rate Matcher 605 etc. is itself an implicit indication of the activation of the disclosed Link Adaptation scheme).

The Rate Matcher (RM) 605, Data/Control Multiplexing, Channel Interleaving 607 and the Modulation mapping 609 entities apply this MCS value 505 to the prepared TB 504, to generate symbols 604 which are then multiplexed 615 in a pre-determined fashion with the MCS symbols 606, prior to DFT-spreading 617.

The Resource Mapping unit in the PUSCH transmitter undergoes modification with respect to the original design of the LTE PUSCH transmitter. The remainder of the

transmitter processing is unchanged: Data and pilot multiplexing 619, Inverse FFT 625, half-carrier shift and Cyclic Prefix insertion 627, all occur without modification.

A typical LTE link adaptation cycle is described in the following section:

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In a first step, the UE receives downlink data and pilots. In a second step, the UE estimates the channel. In a third step, the UE calculates SINR for each subcarrier based on estimated channel in step 2. In a fourth step, UE computes a compressed or 'effective' SINR value from the individual SINRs calculated above and then computes a CQI value based on the chosen Link Quality Mapping (LQM) function. Essentially, the LQM function maps the instantaneous channel state into a single scalar value, an effective SINR which is then used to find an estimate of the BLER for this channel state. There are two main types of LQM functions, Exponential Effective SINR mapping (EESM) and Mutual Information Effective SINR Mapping (MIESM). EESM is explained below (see table 1). In a fifth step, UE transmits uplink data, in particular CQI and/or other control information and optionally a wideband pilot (SRS) to eNodeB through uplink channel. In a sixth step, eNodeB receives uplink data, and demodulates and decodes it using the uplink DMRS pilots, computing the SINR and a Channel Quality metric in the process. In a seventh step, eNodeB schedules UEs for both downlink and uplink. In an eighth step, eNodeB decides MCS of each UE scheduled in the downlink depending on the CQI computed in Step 4. In a ninth step, eNodeB decides MCS of each UE scheduled in the uplink depending on several inputs: channel quality metric computed in step 6., Uplink Block Error Rate (BLER) over a pre-defined or time-varying window, instantaneous SINR computed in Step. 6, amount of data pending in the UE uplink buffer (in particular obtained through buffer status reports from the UE), etc. In a tenth step, MCS selected in steps 8 and 9 is chosen to achieve a target criterion, for example: Average BLER over 100 transmissions (Moving average) < 10%. BLER is the number of NACKed Transport Blocks / Total number of scheduled Transport Blocks. A Transport Block is NACKed if the Turbo Decoding operation at the Receiver is not successful or the overall Transport Block CRC checksum fails.

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Other criteria based on QoS or QoE can be reduced to a BLER target criterion: For example, for interactive video (e.g. video conferencing), a BLER target of 1% may be suitable for premium subscribers.

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An effective exponential SINR mapping is as follows:

$$SNR_{eff} = -\beta \log \left(\frac{1}{N} \sum_{i=1}^N \exp \left(-\frac{\gamma_i}{\beta} \right) \right)$$

Downlink CQI may be measured by post-equalization SINR values of the resources of interest γ_i (for example: N subcarriers corresponding to the entire bandwidth, i.e. wideband CQI). β is a MCS-dependent calibration factor.

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Table 1 illustrates an example of such an exponential SINR mapping:

MCS index	Modulation order	Code Rate x 1024	β	SINR threshold (dB)
0	QPSK	78	1.0	-9.478
1	QPSK	120	1.4	-6.658
2	QPSK	193	1.4	-4.098
3	QPSK	308	1.48	-1.798
4	QPSK	449	1.5	0.399
5	QPSK	602	1.62	2.424
6	16QAM	378	3.1	4.489
7	16QAM	490	4.32	6.367
8	16QAM	616	5.37	8.456
9	64QAM	466	7.71	10.266
10	64QAM	567	15.5	12.218
11	64QAM	666	19.6	14.122
12	64QAM	772	24.7	15.851
13	64QAM	874	27.6	17.786
14	64QAM	948	28.0	19.811

Table 1: Example of an exponential SINR mapping

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The parts of CQI index, modulation order and code rate are standardized in 3GPP (Table 7.2.3-1, 36.213). The parts of β and SINR threshold are implementation dependent.

Figure 7 shows a schematic diagram illustrating an exemplary uplink signal processing

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700 in the LTE uplink transmitter 600 according to an implementation form.

The UE MAC block 701 may implement the MAC block 601 shown in Figure 6, the Rate Matching block 709 may implement the rate matching block 605 shown in Figure 6, the Data and Control Multiplexing block 721 may implement the data and control multiplexing section of block 607 shown in Figure 6 and the Channel Interleaving block 723 may
 5 implement the channel interleaving section of block 607 shown in Figure 6. Further blocks transport block CRC attachment 703, code block segmentation code block CRC attachment 705 and channel coding 707 are included between UE MAC 701 and Rate Matching 709. A code block concatenation 711 is included between Rate Matching 709 and data and control multiplexing 721. Respective channel coding blocks 713, 715, 717,
 10 719 are used for coding the inputs CQI 608, PMI 610, RI 614, HARQ ACK/NACK 612 and MCS 702. The selected MCS value 702 that may correspond to the value 502 shown in Figures 6 and 5, which may be generated by the UE MAC block 701 is provided together with the indication "Ind" 704 to activate the disclosed link adaptation scheme to the rate matching module 709, the data and control multiplexing block 721 and the channel
 15 interleaving block 723, e.g. as described above with respect to Figure 6. Alternatively, the indication can also be communicated implicitly in the signaled MCS or in an earlier signal.

The impact on UL-SCH Processing is shown in Figure 7. Modified blocks, i.e. modified with respect to the original design of the LTE transmitter, are shaded and newly added blocks
 20 are shown in light pattern. Dashed lines show the indication 704 from UE MAC 701 informing the other entities that the disclosed link adaptation scheme is activated, as well as informing them of the chosen, i.e. selected MCS 702.

The total bits output from the Rate Matcher 709 (G) for the complete Transport Block, is
 25 modified according to the number of coded bits used for the MCS value (Q_{MCS}).

$$G = N_{\text{sym}}^{\text{PUSCH}} \cdot M_{\text{sc}}^{\text{PUSCH}} \cdot Q_m - Q_{\text{CQI}} - Q_{\text{RI}} - Q_{\text{MCS}}$$

where $G, N_{\text{sym}}^{\text{PUSCH}}, M_{\text{sc}}^{\text{PUSCH}}, Q_m, Q_{\text{CQI}}, Q_{\text{RI}}$ are as defined in Section 5.2.2.6 of 3GPP TS 36.212 "Multiplexing and Channel Coding".

30 The output of the Data and Control Multiplexing 721 is based on the updated value of G (described above), which is inferred from the Indication 704 and MCS value 702 received from the UE MAC entity 701.

The channel interleaver 723 has an additional input – the vector sequence output of the
 35 channel coding for the MCS value: $\underline{q}_0^{\text{MCS}}, \underline{q}_1^{\text{MCS}}, \underline{q}_2^{\text{MCS}}, \dots, \underline{q}_{Q'_{\text{MCS}}-1}^{\text{MCS}}$, where $Q'_{\text{MCS}} = Q_{\text{MCS}} / Q'_m$,

where Q_{MCS} is the number of coded symbols for MCS, which is pre-decided between the base station and the user equipment, and Q'_m is the modulation order for the coded MCS symbols, which is also pre-decided. The channel interleaver 723 output bit sequence is obtained in such a fashion as to map the coded MCS bits to pre-defined positions on the time-frequency resource grid, after modulation, e.g. as shown in the exemplary resource grid of Figure 8.

Figure 8 shows an exemplary realization of a time-frequency resource grid 800 after channel interleaving in the LTE uplink transmitter 600 according to an implementation form.

The resource grid 800 includes two slots 802, each having an exemplary number of 7 symbols, e.g. SC-FDMA symbols 804 and an exemplary number of 24 subcarriers 806. The resource grid 800 includes CQI symbols, RS (reference signal) symbols, RI (rate indicator) symbols, A/Nack (Acknowledgement or Non-Acknowledgement) symbols and MCS (modulation and coding scheme) symbols. The remaining resource elements are occupied by data.

Note that the position of the MCS symbols within the PUSCH allocation is flexible and could potentially alter the positions of the other elements, e.g. CQI elements, as shown in Figure 8, but has to be pre-decided between the base station and the user equipment.

Figure 9 shows a block diagram illustrating an exemplary PUSCH processing chain 900 in the LTE uplink transmitter 600 according to an implementation form. The PUSCH processing chain 900 includes the successively arranged blocks scrambling 901, modulation mapper 903, transform precoder 905, resource element mapper 907 and SC-FDMA signal generation 909.

The modified entities, i.e. modified with respect to the original LTE transmitter, are Scrambling 901 and Resource element mapping 907.

In the scrambling block 901, the scrambling operation is applied to the MCS coded bits just as the Data or channel quality coded bits, Rank Indication coded bits or ACK/NACK coded bits. Depending on the Channel Coding scheme chosen for the MCS bits, if there exist placeholder bits in the encoded MCS bit sequence, the scrambling operation will

select the placeholder bits so as to maximize the Euclidean distance of the modulation symbols carrying the MCS information, according to the pre-decided modulation scheme.

5 The modulation mapping unit 903 modulates the scrambled MCS bits according to the pre-decided modulation order Q'_m and modulates the rest of the scrambled PUSCH bits according to the UE-selected modulation order Q_m .

10 The Resource Element Mapper unit 907 maps the complex-valued modulated MCS symbols in pre-determined positions in the Time-Frequency Resource grid and the rest of the complex-valued modulated PUSCH symbols accordingly to the regular assignment rules specified in Section 5.3.4 of 3GPP TS 36.212 "Physical channels and modulation".

15 Figure 10 shows a block diagram illustrating an uplink receiver 1000 for a base station for communication to a user equipment (UE) according to an implementation form. The uplink receiver 1000 includes a reception module 1001, a demodulation and decoding module 1003, and an uplink signal processing chain 1005.

20 The reception module 1001 is configured to receive a radio signal comprising UE modulation and coding scheme (MCS) symbols 1002 and uplink data symbols 1004, possibly being multiplexed with legacy control information (CQI, HARQ, etc.), e.g. as transmitted by a transmission module 507 of an uplink transmitter 500 over a communication channel as described above with respect to Figure 5.

25 The demodulation and decoding module 1003 is configured to demodulate and decode the UE MCS symbols 1002 according to a predetermined BS MCS, e.g. corresponding to the BS MCS 510 as described above with respect to Figure 5 to provide a decoded UE MCS value 1006.

30 The uplink signal processing chain 1005 is configured to demodulate and decode the uplink data symbols 1004 based on the decoded UE MCS value 1006 to provide uplink data bits 1008 decoded by the UE MCS value 1006.

35 The uplink signal processing chain 1005 may be configured to de-multiplex the UE MCS symbols 1002 from the uplink data symbols 1004 according to a predetermined de-multiplexing scheme, in particular a de-multiplexing scheme predetermined by the BS.

The uplink signal processing chain 1005 may include a channel de-interleaver and a data and control de-multiplexer, e.g. a block 1123 as described below with respect to Figure 11 which are configured to separate the uplink data symbols 1004 into data bits and control bits according to the decoded UE MCS value 1006. The control bits may include CQI bits 608, PMI bits 610, ACK bits, NACK bits 612 and RI bits 614, e.g. as described above with respect to Figure 6.

The uplink signal processing chain 1005 may include a rate de-matcher, e.g. a block 1125 as described below with respect to Figure 11, configured to output a rate de-matched coded bit-stream 1126 according to the decoded UE MCS value 1006.

Figure 11 shows a block diagram illustrating an LTE uplink receiver 1100 for a base station according to an implementation form.

The design of the uplink receiver 1100 incorporates and enables the novel link adaptation function in the base station. Figure 11 shows one realization of the general receiver design 1000 shown in Figure 10, under the assumption of LTE Uplink receiver.

The uplink receiver 1100 includes a reception module (not depicted in Figure 11), a demodulation and decoding module 1003, and an uplink signal processing chain 1005.

The reception module is configured to receive a radio signal comprising UE modulation and coding scheme (MCS) symbols 1002 and uplink data symbols 1004, e.g. as transmitted by a transmission module of an uplink transmitter 500, 600 over a communication channel as described above with respect to Figures 5 and 6.

The demodulation and decoding module 1003 including a soft demodulator 1117 and a decoder 1119 is configured to demodulate and decode the UE MCS symbols 1002 according to a predetermined BS MCS, e.g. corresponding to the BS MCS 510 as described above with respect to Figures 5 and 6 to provide a decoded UE MCS value 1006.

The uplink signal processing chain 1005 is configured to demodulate and decode the uplink data symbols 1004 based on the decoded UE MCS value 1006 to provide uplink symbols 1126 decoded by the UE MCS value 1006.

The uplink signal processing chain 1005 may include an MCS demultiplexer 1115 that may be configured to de-multiplex the UE MCS symbols 1002 from the uplink data symbols 1004 according to a predetermined de-multiplexing scheme, in particular a de-multiplexing scheme predetermined by the BS.

- 5 The uplink signal processing chain 1005 may include a channel de-interleaver and a data and control de-multiplexer 1123 which are configured to separate the uplink data symbols 1004 into data bits and control bits according to the decoded UE MCS value 1006. The control bits may include CQI bits 608, PMI bits 610, ACK bits, NACK bits 612 and RI bits 614, e.g. as described above with respect to Figure 6.

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The uplink signal processing chain 1005 may include a rate de-matcher 1125 configured to output a rate de-matched coded bit-stream 1126 according to the decoded UE MCS value 1006.

- 15 The signal that is received by the uplink receiver 1100 first passes a cyclic prefix and half shift block 1101, an FFT block 1103, a frame demapper 1105 a DMRS demultiplexer 1107 separating DMRS reference signal from the received signal for channel estimation 1109, an equalizer 1111 and an IDFT block 1113 before it is provided to the MCS demultiplexer 1115.

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The uplink receiver 1100 at the base station works in conjunction with the Transmitter design presented above with respect to Figure 6. Figure 11 shows a realization of the receiver 1100 in the form of an LTE Uplink PUSCH receiver.

- 25 An exemplary functionality of the above described blocks is described in the following section.

After the frequency-domain channel estimation 1109, equalization 1111 and application of Inverse-DFT 1113, the time-domain MCS symbols 1002 are de-multiplexed 1115 from the remaining data symbols 1004. These symbols 1002 are then soft-demodulated 1117 and decoded 1119 based on the pre-decided (eg: via signalling) modulation and coding scheme for these symbols. The decoded MCS value 1006 is fed to the soft-demodulator 1121 which then decodes the rest of the PUSCH data & control symbols 1004 based on the chosen modulation type 1006. The decoded MCS value 1006 is also fed to the

- 35 Channel De-Interleaver and Data/Control de-multiplexing entities 1123 which use this information to separate out the coded PUSCH data bits and the coded PUSCH control bits viz. CQI 608, PMI 610, ACK/NACK 612, RI 614. The decoded MCS value 1006 is also fed

to the Rate De-matcher 1125, which uses the decoded MCS value 1006 and the total bits fed to it, to output the rate-dematched coded bit-stream 1126 to the Turbo Decoder 1127. The remainder of the uplink receiver processing remains unchanged with respect to the original LTE receiver design.

- 5 The key idea in the receiver 1100 can be summarized as follows: The MCS used to encode the PUSCH data is selected by the user equipment. Hence, in order to decode the PUSCH data, this MCS is signalled along with the PUSCH data in a pre-determined format. The receiver first decodes this MCS value and then uses this information to decode the actual PUSCH data.

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Figure 12 shows a schematic diagram illustrating a signaling message diagram 1200 for activating or deactivating the UE link adaptation scheme according to an implementation form.

- 15 The disclosed link adaptation scheme is most beneficial in situations where low-latency (or high-reliability) is essential. In other situations, it may be unnecessary and may increase processing and battery consumption at the user equipment. In order to optimize the system performance, it may be necessary to activate/de-activate the disclosed link adaptation scheme on a per-UE basis as the situation demands.

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Hence, broadly, two alternative signalling methods may be applied for controlling the disclosed scheme – an on-demand activation 1200a based on dedicated control signalling and a semi-static activation 1200b involving dedicated RRC signalling or cell-wide System Information (SI) message broadcasts. These methods are shown in Figure 12, again in the context of an LTE system.

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With respect to the on-demand activation 1200a, the DCI 0A (1201) is a modified form of DCI 0 (which is used to signal the uplink grants in LTE). The reason for the modification is primarily to inform the UE to apply the disclosed scheme for the uplink transmission corresponding to the uplink grant. The disclosed link adaptation scheme does not require the MCS to be signaled to the user equipment as this is decided by the user equipment (see Figure 13 below). Hence the reduced message size of DCI message can increase the overall PDCCH capacity (more users) or PDCCH reliability (better Control Channel performance) of the cell. Alternatively, the MCS can be signaled in the DCI 0 (as in the normal case) and the UE can apply an MCS offset to the signaled MCS depending on its preferred MCS based on the latest available channel quality at the UE. This alternative

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has the advantage of lower signaling overhead on the uplink (as opposed to the downlink).

With the semi-static activation 1200b, the enabling/disabling of the link adaptation scheme
5 can be done by the base station for a particular UE, for a specific radio bearer and/or with a specific periodicity (e.g. semi persistent scheduling uplink grants), or for cell-wide activations via broadcast signaling (via system information blocks).

The signaling also includes procedures for controlling the dynamic range of UE-centric link
10 adaptation, depending on measured channel variations, for example. The signaling exchanges between transmitter and receiver may also include calibration coefficients to maintain the channel reciprocity assumption at the user equipment and provide better estimates of uplink channel based on downlink pilots.

Figure 13 shows an exemplary downlink control information (DCI) table 1300 according to
15 an implementation form illustrating exemplary contents of DCI Format 0. The table 1300 corresponds to the LTE standard. An optional field "ModCoding" 1301 in modified DCI format 0A of size 5 bits is used for indicating the modulation, coding scheme and redundancy version.

20 Figure 14 shows a performance diagram 1400 illustrating an exemplary target benefit of a link adaptation scheme according to the disclosure.

The disclosed UE-centric link adaptation scheme effectively mitigates the problem of
25 CQI/CSI aging in state-of-the-art uplink link adaptation schemes and thus improves uplink performance, particularly in fast time-varying channels. As shown in Figure 14, the target of the disclosed link adaptation scheme is to enable both ultra-reliable and ultra-low latency communication for the uplink as illustrated by field R4.

30 As the disclosed scheme can be activated on demand by the eNodeB or the UE, the improved performance can be achieved selectively depending on the service requirements and/or UE capabilities. This flexible trade-off between performance and complexity is an enabler for 5G communications.

35 The additional signalling overhead of transmitting the UE-selected MCS in-band with the uplink data is very small, and reduces with larger uplink resource allocations as seen in Figure 15. The effect of this overhead is a slightly higher code-rate for PUSCH data and/or

UCI. This overhead is offset on the downlink control channel (PDCCH) where there is no need to transmit the 5-bit MCS in the DCI Format 0. This can lead to coding or capacity gains on the downlink control channel.

Figure 15 shows a performance diagram 1500 illustrating an exemplary MCS signaling overhead versus the number of allocated resource blocks. The graph 1501 illustrates MCS overhead for an RM (20,5) block code, QPSK. The graph 1502 illustrates MCS overhead for an RM (20,5) block code, 16QAM. The graph 1503 illustrates MCS overhead for an RM (20,5) block code, 64 QAM.

Figure 16 shows a view on a vehicle to infrastructure (V2X) communication system 1600 applying a link adaptation scheme according to the disclosure.

The most appropriate application of the disclosed scheme is for enabling LTE-based V2X communication with tight requirements on uplink latency. The benefit is greater when the uplink traffic profile is both time-critical and irregular/infrequent (ex.: ITS DENM messages) and when the wireless propagation conditions are varying rapidly with time. As an example application, consider the emergency warning scenario in Figure 16 where car A, equipped with a cellular transceiver, has an emergency and needs to immediately notify all surrounding cars B, C and D (and possibly pedestrians), to avoid impending accidents. Besides employing direct D2D communication (the most efficient in this case), there is a need to notify the base station which can broadcast or multicast the relevant information to the nodes in the vicinity. This is important if the D2D communication fails due to a deep fade or shadowing between the transmitting and receiving devices.

Other very attractive applications of the disclosed link adaptation scheme include Machine Type Communications (MTC) and Cellular-IoT – particularly the use cases requiring low latency and high reliability but low data rates. Classic examples of such use cases are industrial automation (e.g.: remote robot control), and continuous remote monitoring (e.g.: cranes or construction equipment). The disclosed link adaptation scheme can therefore be applied to narrowband cellular M2M such as LTE-M or similar variants.

Figure 17 shows a block diagram illustrating a communication system 1700 according to an implementation form in which hardware imperfections affect channel reciprocity. The upper part 1701, 1703, 1705, 1707 represents downlink transmission from eNB (base station) to UE, while the lower part 1709, 1711, 1713, 1715 represents uplink transmission from UE to eNB. The uplink transmitter is represented by the blocks 1709, 1711 that may

correspond to the uplink transmitter 500, 600 described above with respect to Figures 5 and 6. The uplink receiver is represented by the blocks 1713, 1715 that may correspond to the uplink receiver 1000, 1100 described above with respect to Figures 10 and 11.

- 5 The disclosed scheme relies on the channel reciprocity assumption in order to perform link adaptation at the user equipment. This means that the UE uses the downlink Channel State Information to estimate the uplink channel conditions. In theory the propagation channel can be assumed to be nearly reciprocal if the time interval between UL and DL transmission is much less than the coherence time of the propagation channel (generally true). However, in practice, the transceiver circuits are usually not reciprocal i.e. the TX and RX frequency responses are different, which destroys the reciprocity assumption (see the differences in blocks 1703, 1713 and blocks 1705, 1711 shown in Figure 17). Hence, RF calibration may be required between TX/RX of eNB and UE in order to maintain the reciprocity assumption and preserve the accuracy and performance of the link adaptation at the UE.

In the following description of TX/RX RF calibration, the following terms and abbreviations are applied: T_{BS} and R_{BS} are square diagonal matrices of size m , and denote the TX response and RX response of m antenna/transceivers respectively, at the base station (eNB). T_{UE} and R_{UE} are square diagonal matrices of size n , and denote the TX response and RX response of n antenna/transceivers respectively, at the user equipment (UE). X_D and X_U denote the DL and UL transmitted data symbol vectors respectively. W is the DL precoding matrix, H is the propagation channel on the downlink from eNB to UE, N_0 is the Gaussian noise at the receiver. The DL received signal is written as $y_D = H_D \times W \times X_D + N_0$ where $H_D = R_{UE} \times H \times T_{BS}$. The UL received signal is written as $y_U = H_U \times X_U + N_0$ where $H_U = R_{BS} \times H^T \times T_{UE}$.

From the above, the following relations can be derived:

$$H_U^T = T_{UE}^T \times H \times R_{BS}^T \text{ and } H = (T_{UE}^T)^{-1} \times H_U^T \times (R_{BS}^T)^{-1} \text{ and}$$

$$H_D = R_{UE} \times (T_{UE}^T)^{-1} \times H_U^T \times (R_{BS}^T)^{-1} \times T_{BS}.$$

From the above equations it is clear that if we do not have $R_{UE} \times (T_{UE}^T)^{-1} = I$ and $(R_{BS}^T)^{-1} \times T_{BS} = I$ (I : Unit Matrix), the effective DL and UL channels will be different. Hence, to restore reciprocity a calibrated channel $H_{D,C}$ and $H_{U,C}$ can be introduced. The calibrated channel is generated from the effective channel by applying precoding in the two transmitters as follows:

$$\text{Downlink calibrated channel: } H_{D,C} = H_D K_{BS}$$

Uplink calibrated channel: $H_{U,C} = H_U K_{UE}$,

where $K_{BS} = R_{BS}/T_{BS}$ and $K_{UE} = R_{UE}/T_{UE}$ are square diagonal matrices of size m and n representing the calibration factor at the eNB and UE, respectively. The calibration
5 process is basically to derive K_{BS} and K_{UE} at both eNB and UE.

The disclosed link adaptation scheme entails the exchange of such calibration factors (or methods to derive the same) between the user equipment and base station in order to keep the channel reciprocity between uplink and downlink and thus ensure better
10 performance of the uplink link adaptation.

Figure 18 shows a schematic diagram illustrating a method 1800 for signaling link adaptation control to an uplink transmitter of a user equipment according to an implementation form. The uplink transmitter may correspond to the uplink transmitter 500,
15 600 described above with respect to Figures 5 and 6.

The method 1800 includes: transmitting 1801 a message from a base station (BS) to the user equipment (UE), the message comprising information indicating an enabling or disabling of a UE modulation and coding scheme (MCS) selection; and enabling or
20 disabling 1802 the UE MCS selection in a link adaptation module of an uplink transmitter of the UE according to the information received from the BS.

The method 1800 may further include: transmitting 1801 the message by one of semi-static signaling via RRC messages or on-demand signaling via downlink control signals, e.g. as described above with respect to Figure 12; controlling a dynamic range of the link
25 adaptation module; and exchanging calibration coefficients between the BS and the UE, the calibration coefficients indicating a channel reciprocity between downlink and uplink transmission, e.g. as described above with respect to Figure 17.

The present disclosure also supports a computer program product including computer executable code or computer executable instructions that, when executed, causes at least one computer to execute the performing and computing steps described herein, in particular the steps of the method 1800 described above with respect to Figure 18. Such a computer program product may include a readable non-transitory storage medium storing
30 program code thereon for use by a computer. The program code may perform the method 1800 described above with respect to Figure 18.
35

While a particular feature or aspect of the disclosure may have been disclosed with respect to only one of several implementations, such feature or aspect may be combined with one or more other features or aspects of the other implementations as may be desired and advantageous for any given or particular application. Furthermore, to the extent that the terms “include”, “have”, “with”, or other variants thereof are used in either the detailed description or the claims, such terms are intended to be inclusive in a manner similar to the term “comprise”. Also, the terms “exemplary”, “for example” and “e.g.” are merely meant as an example, rather than the best or optimal. The terms “coupled” and “connected”, along with derivatives may have been used. It should be understood that these terms may have been used to indicate that two elements cooperate or interact with each other regardless whether they are in direct physical or electrical contact, or they are not in direct contact with each other.

Although specific aspects have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that a variety of alternate and/or equivalent implementations may be substituted for the specific aspects shown and described without departing from the scope of the present disclosure. This application is intended to cover any adaptations or variations of the specific aspects discussed herein.

Although the elements in the following claims are recited in a particular sequence with corresponding labeling, unless the claim recitations otherwise imply a particular sequence for implementing some or all of those elements, those elements are not necessarily intended to be limited to being implemented in that particular sequence.

Many alternatives, modifications, and variations will be apparent to those skilled in the art in light of the above teachings. Of course, those skilled in the art readily recognize that there are numerous applications of the invention beyond those described herein. While the present invention has been described with reference to one or more particular embodiments, those skilled in the art recognize that many changes may be made thereto without departing from the scope of the present invention. It is therefore to be understood that within the scope of the appended claims and their equivalents, the invention may be practiced otherwise than as specifically described herein.

CLAIMS

1. An uplink transmitter (500) for a user equipment (UE) for communication to a base station (BS), the uplink transmitter (500) comprising:
 - 5 a link adaptation module (501), configured to select a UE modulation and coding scheme (MCS) (502) based on a target criterion;

an uplink signal processing chain (503), configured to prepare and process an uplink transport block (504) according to the selected UE MCS (502);

a coding and modulation module (505), configured to encode and modulate the
10 selected UE MCS (502) according to a predetermined BS MCS (510);

a transmission module (507), configured to transmit the processed uplink transport block (504) together with the modulated and encoded selected UE MCS (506) over an uplink radio communication channel.
2. The uplink transmitter (500) of claim 1,
 - 15 wherein the target criterion is based on at least one of the following: an average Block Error Rate (BLER), a Quality of Service (QoS) metric, a Quality of Experience (QoE) metric, in particular based on a BLER of 10 percent or 1 percent.
3. The uplink transmitter (500) of claim 1 or 2,
 - 20 wherein the target criterion is based on at least one of the following: at least a subset of a plurality of downlink reference signals, a resource block allocation assigned by the BS, an average BLER over a predetermined or dynamically varying window, a pending data in an uplink buffer and an instantaneous channel condition, in particular a Carrier Frequency Offset (CFO), a reference signal received power (RSRP) or a signal-to-interference-plus noise ratio (SINR).
- 25 4. The uplink transmitter (500) of one of the preceding claims,
 - wherein the link adaptation module (501) is configured to select the UE MCS (502) responsive to a reception of an uplink grant from the BS and/or responsive to a periodically scheduled grant.
5. The uplink transmitter (500) of one of the preceding claims,

wherein the coding and modulation module (505) is configured to encode and modulate the selected UE MCS (602) to generate UE MCS symbols (606) onto a time-frequency resource grid according to the predetermined BS MCS (510).

6. The uplink transmitter (500) of claim 5,

5 wherein the coding and modulation module (505) is configured to allocate the UE MCS symbols (606) at predetermined positions on the resource grid, in particular at positions predetermined by the BS, in particular at first symbol positions of the resource grid.

7. The uplink transmitter (500) of claim 5 or 6,

10 wherein the uplink signal processing chain (503) comprises a media access control (MAC) module (601), configured to prepare the uplink transport block (504) based on the selected UE MCS (502) and a given resource block allocation, in particular a resource block allocation given by the BS.

8. The uplink transmitter (500) of claim 7,

15 wherein the uplink signal processing chain (503) comprises a rate matcher (605), a data and control multiplexer (607), a channel interleaver and a modulator (609) which are configured to apply the selected UE MCS (502) to the prepared uplink transport block (504) to generate uplink data symbols (604) onto the time-frequency resource grid.

9. The uplink transmitter (500) of claim 8,

20 wherein the uplink signal processing chain (503) is configured to multiplex (615) the UE MCS symbols (606) together with the uplink data symbols (604) on the time-frequency resource grid according to a predetermined multiplexing scheme, in particular a multiplexing scheme predetermined by the BS.

10. The uplink transmitter (500) of claim 9,

25 configured to activate and/or deactivate the link adaptation module (501); and/or the uplink signal processing chain (503), in particular based on downlink information.

11. An uplink receiver (1000) for a base station (BS) for communication to a user equipment (UE), the uplink receiver (1000) comprising:

a reception module (1001), configured to receive a radio signal comprising UE modulation and coding scheme (MCS) symbols (1002) and uplink data symbols (1004);

a demodulation and decoding module (1003), configured to demodulate and decode the UE MCS symbols (1002) according to a predetermined BS MCS (510) to
5 provide a decoded UE MCS value (1006); and

an uplink signal processing chain (1005), configured to demodulate and decode the uplink data symbols (1004) based on the decoded UE MCS value (1006).

12. The uplink receiver (1000) of claim 11,

wherein the uplink signal processing chain (1005) is configured to de-multiplex
10 (1115) the UE MCS symbols (1002) from the uplink data symbols (1004) according to a predetermined de-multiplexing scheme, in particular a de-multiplexing scheme predetermined by the BS.

13. The uplink receiver (1000) of claim 11 or 12,

wherein the uplink signal processing chain (1005) comprises a channel de-
15 interleaver and a data and control de-multiplexer (1123) which are configured to separate the uplink data bits (1004) into data bits and control bits according to the decoded UE MCS value (1006), wherein the control bits comprise at least one of the following: CQI bits (608), PMI bits (610), ACK bits, NACK bits (612), RI bits (614).

14. The uplink receiver (1000) of one of claims 11 to 13,

20 wherein the uplink signal processing chain (1005) comprises a rate de-matcher (1125), configured to output a rate de-matched coded bit-stream (1126) according to the decoded UE MCS value (1006).

15. A method (1800) for signaling a link adaptation control to an uplink transmitter of a user equipment, in particular an uplink transmitter (500) according to one of claims 1 to
25 10, the method (1800) comprising:

transmitting (1801) a message from a base station (BS) to the user equipment (UE), the message comprising information indicating an enabling or disabling of a UE modulation and coding scheme (MCS) selection; and

enabling or disabling (1802) the UE MCS selection in a link adaptation module of
30 an uplink transmitter of the UE according to the information received from the BS.

16. The method (1800) of claim 15, comprising:

transmitting (1801) the message by one of semi-static signaling via RRC messages or on-demand signaling via downlink control signals;

controlling a dynamic range of the link adaptation module; and

5 exchanging calibration coefficients between the BS and the UE, the calibration coefficients indicating a channel reciprocity between downlink and uplink transmission.

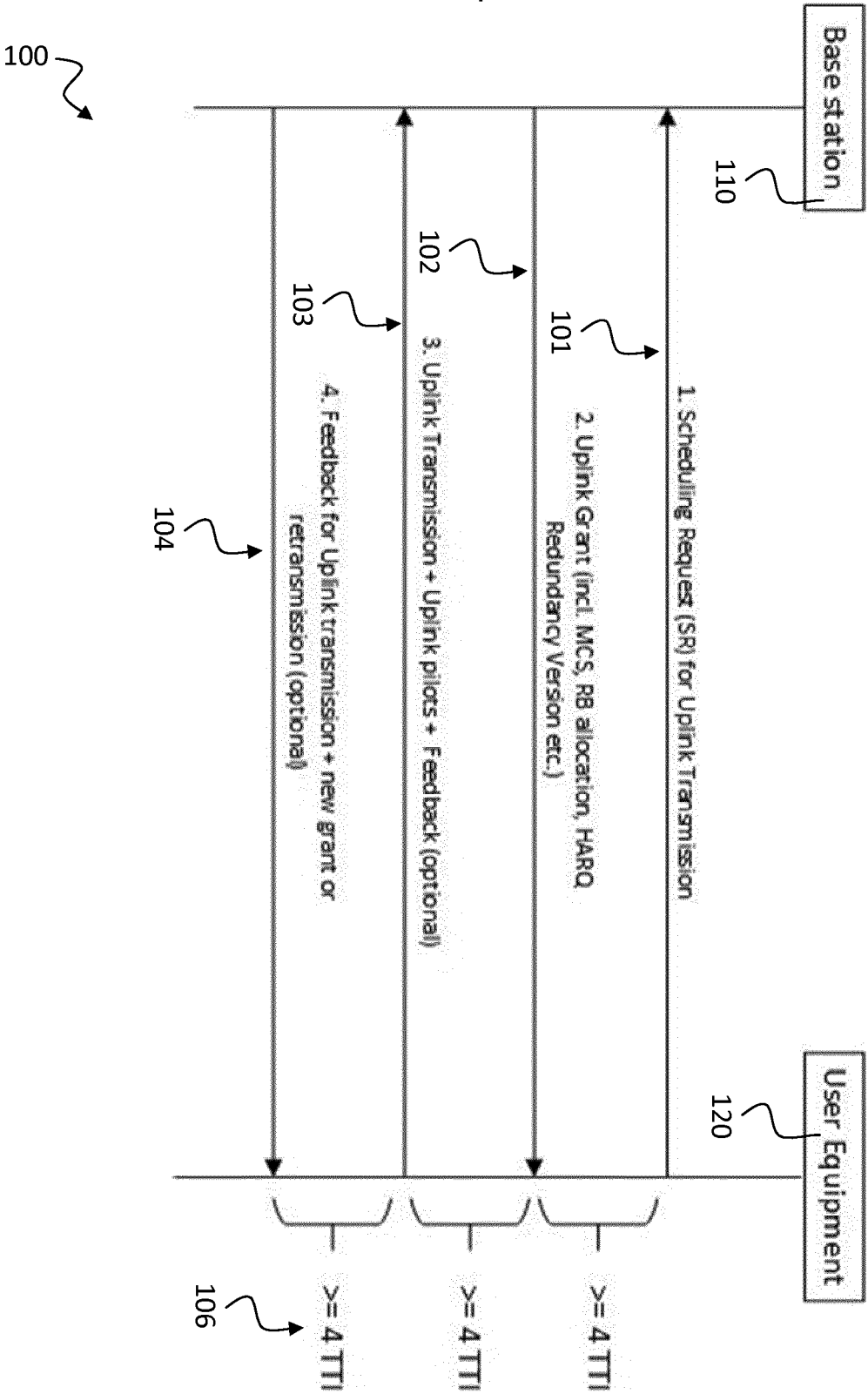


Fig. 1

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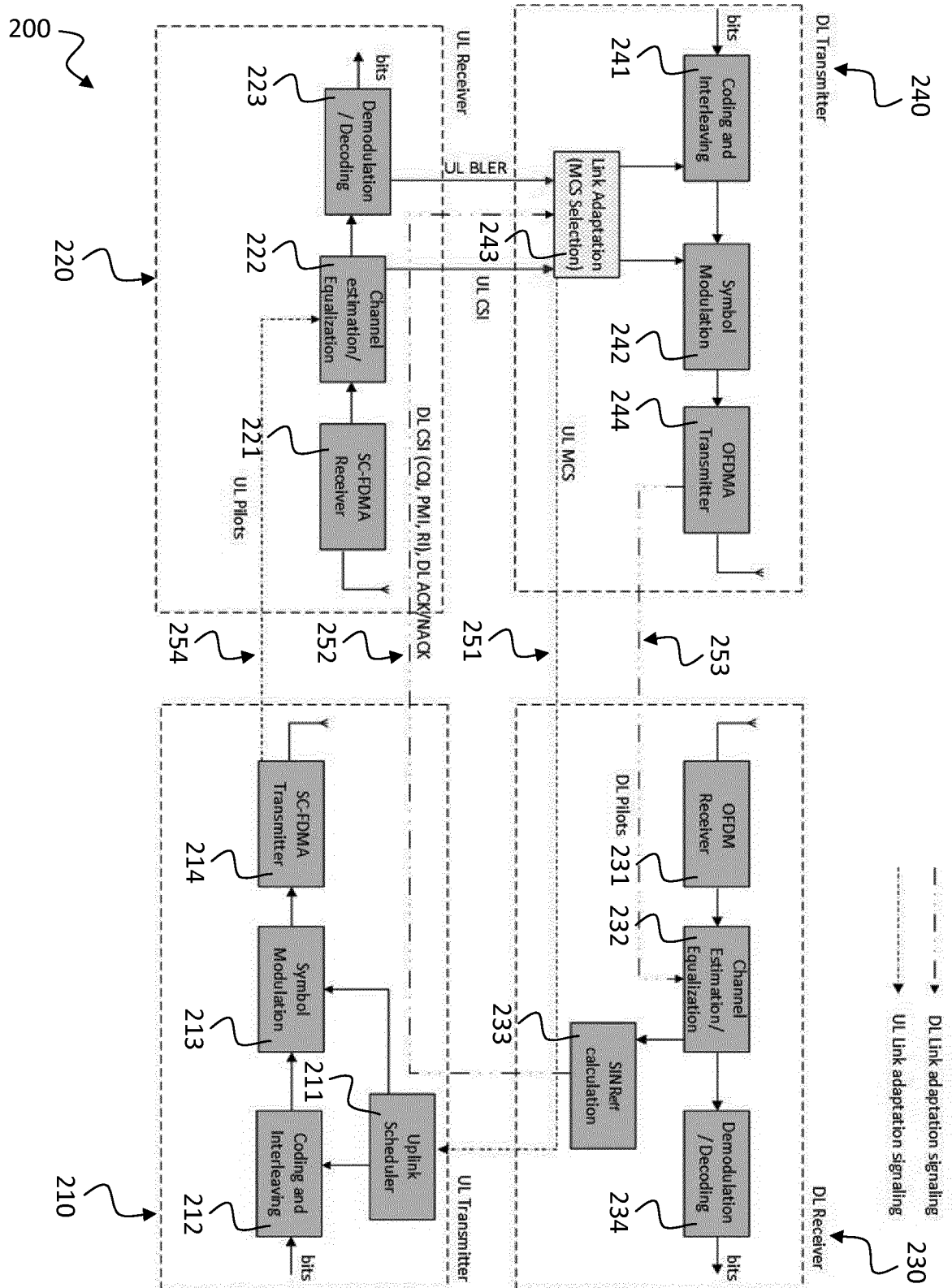


Fig. 2

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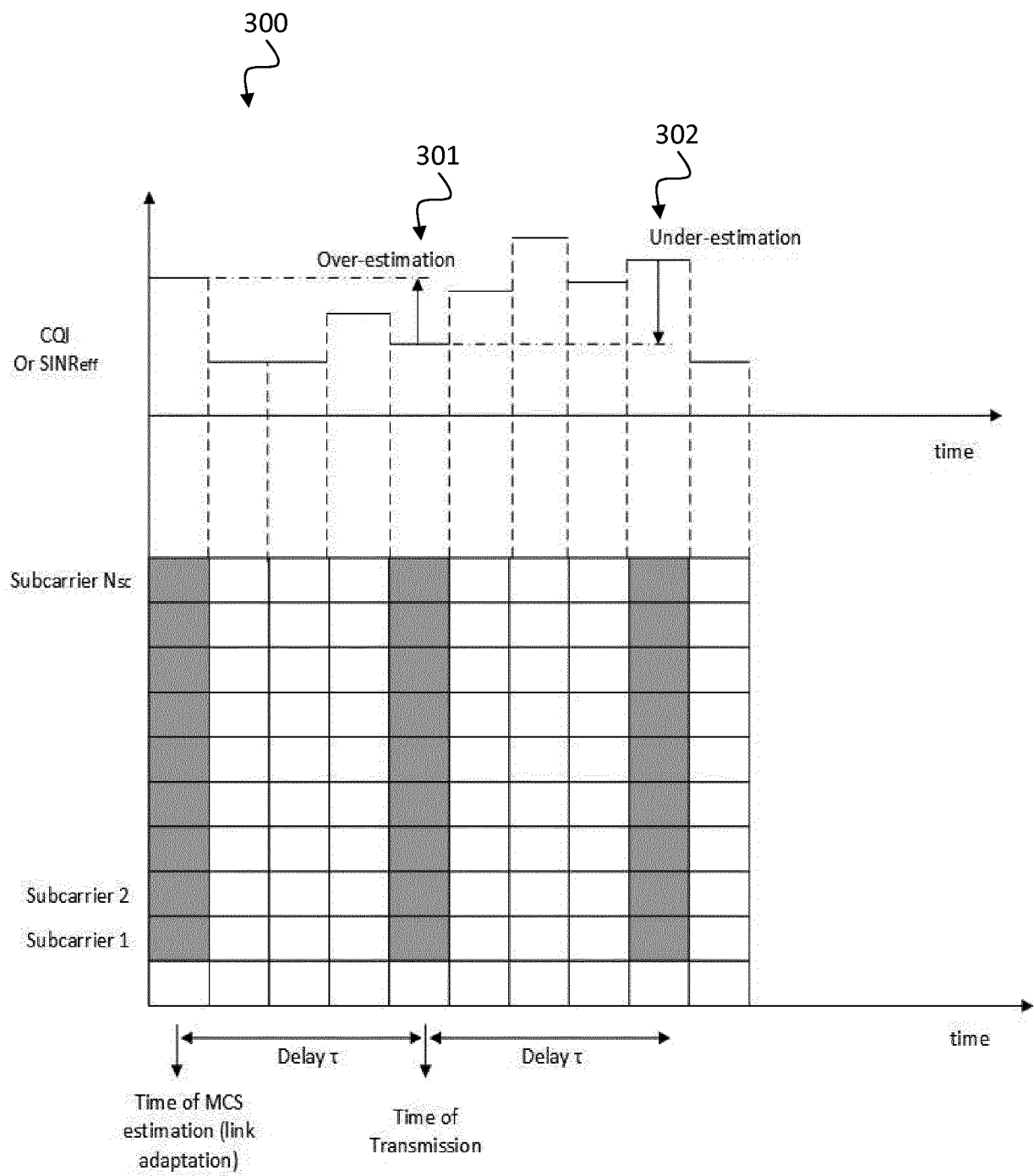


Fig. 3

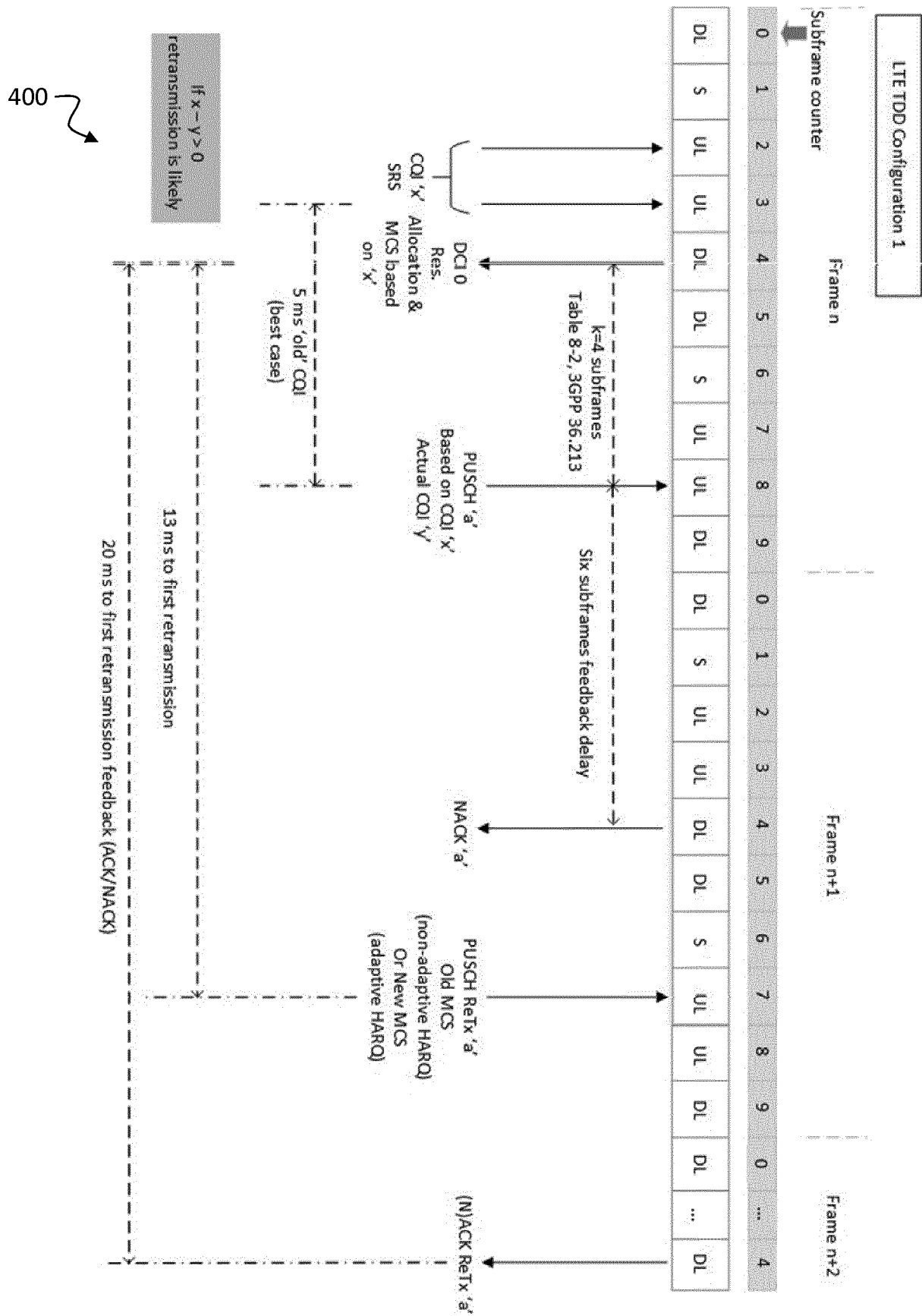


Fig. 4

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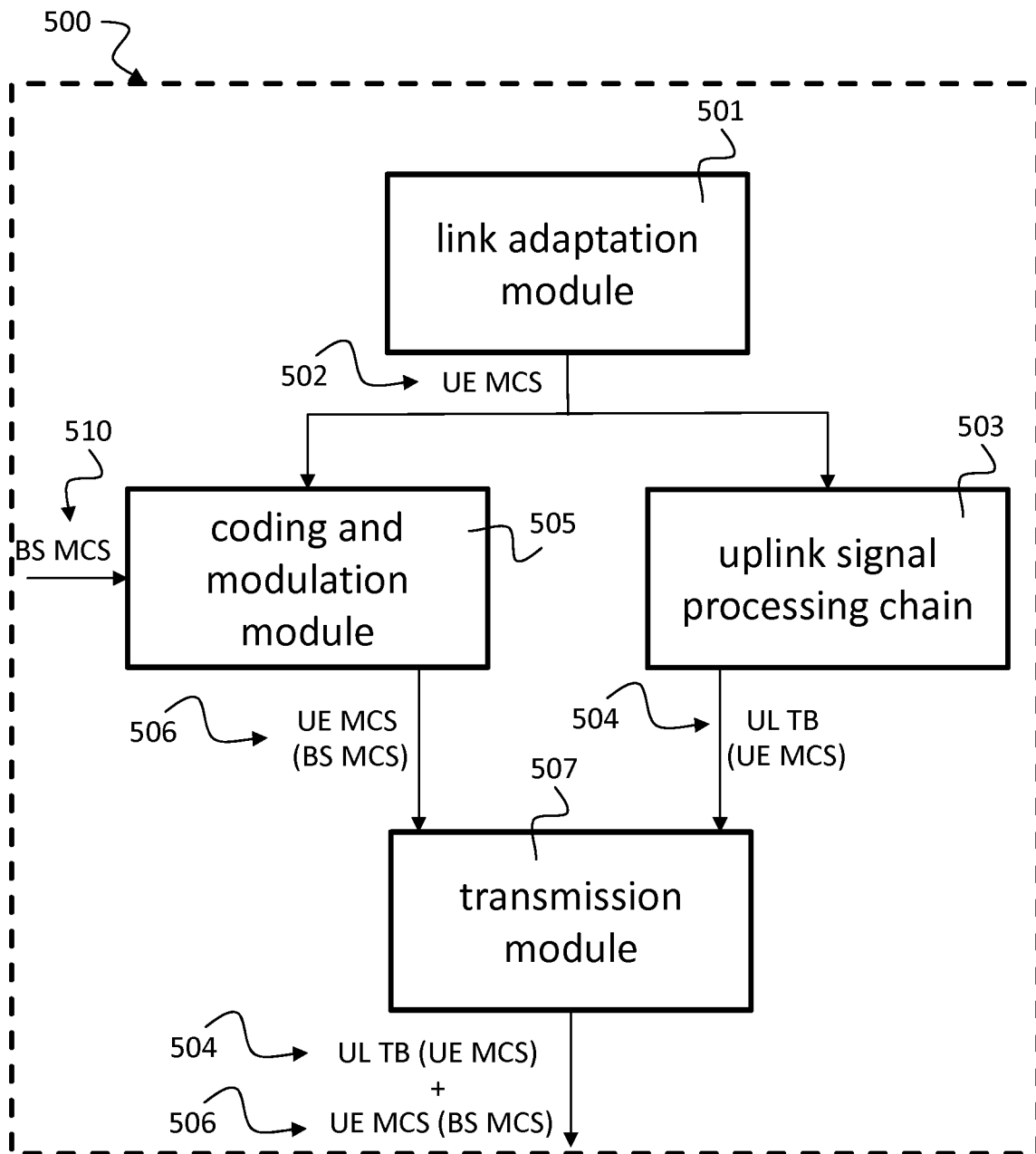


Fig. 5

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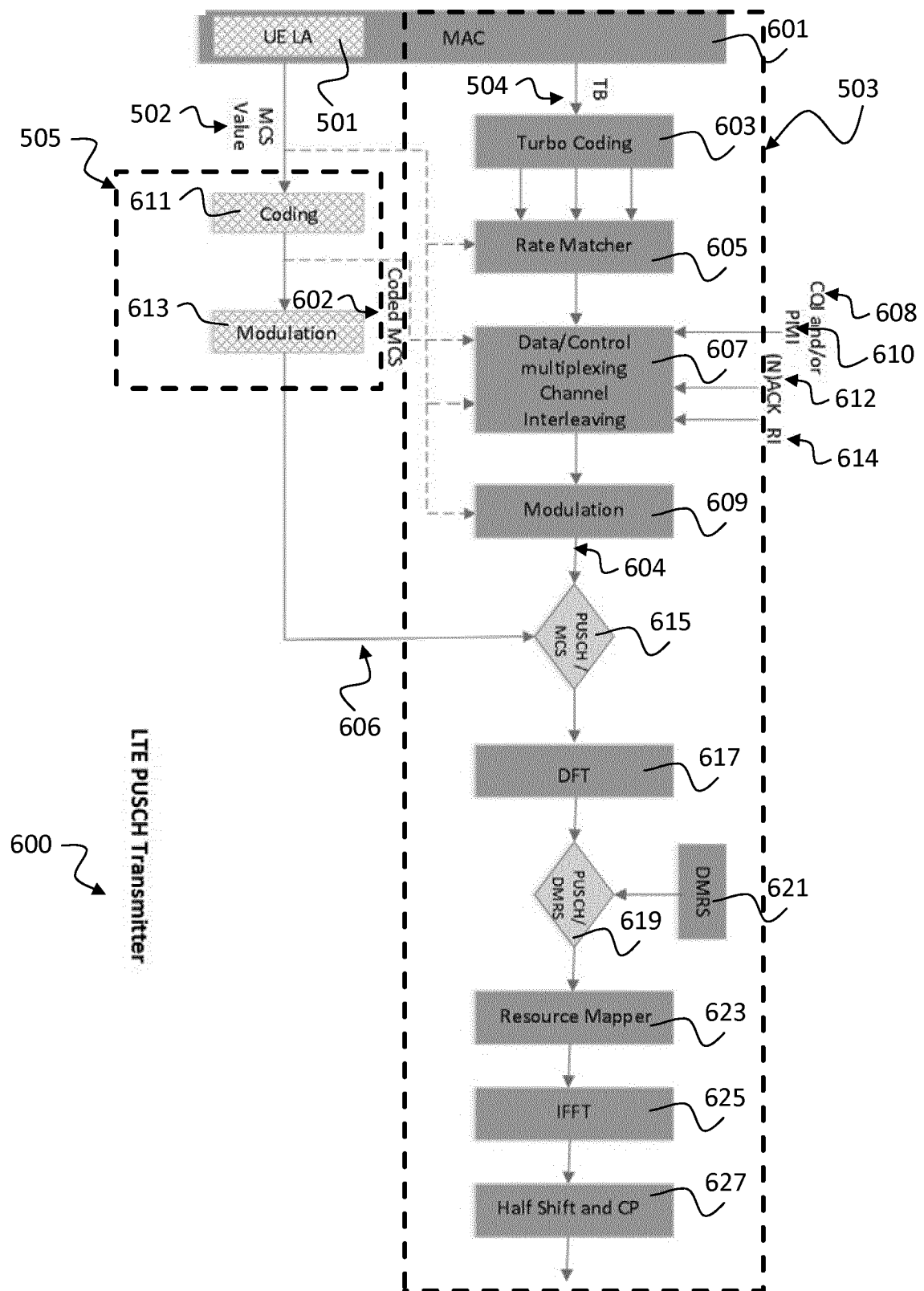


Fig. 6

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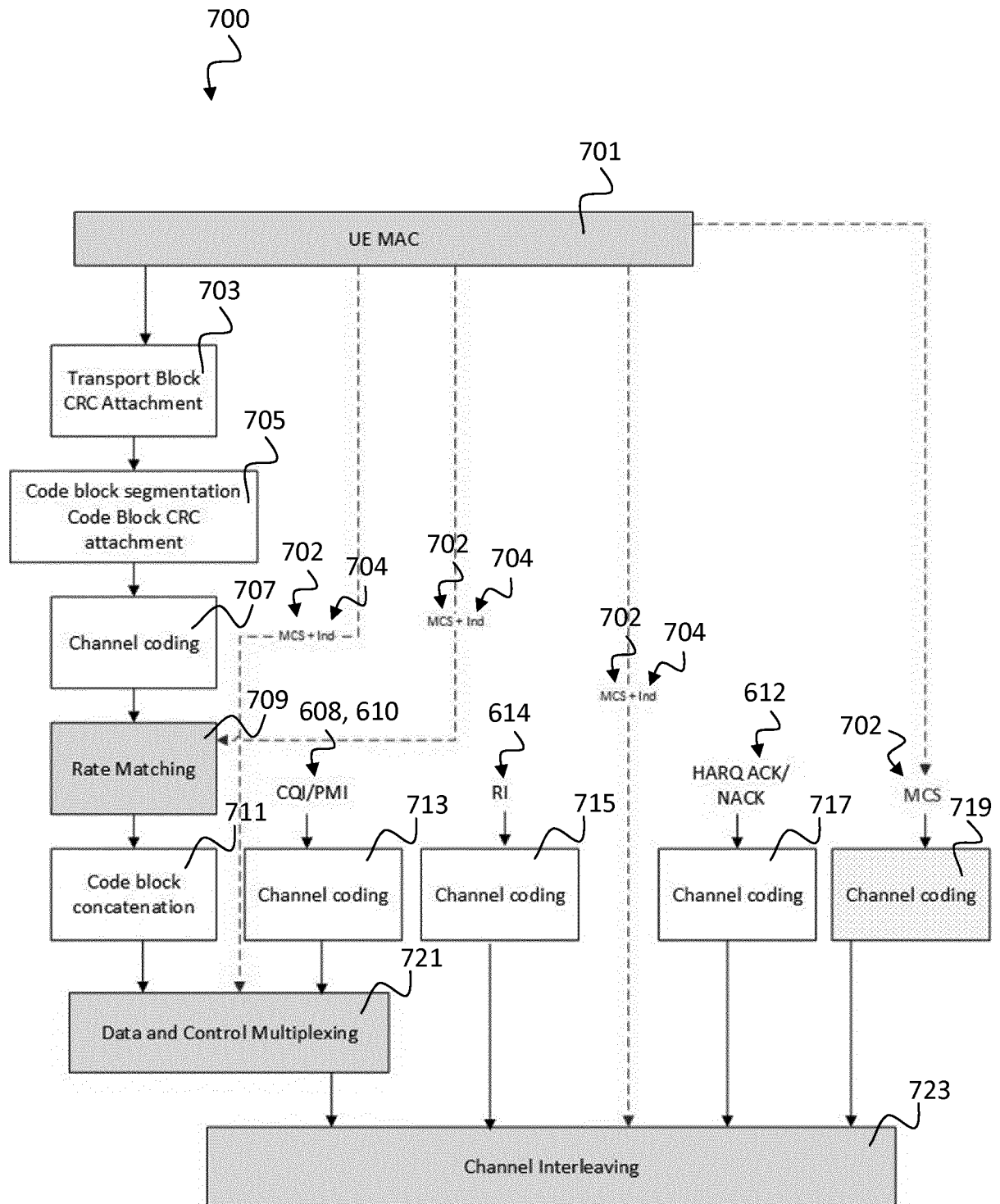


Fig. 7

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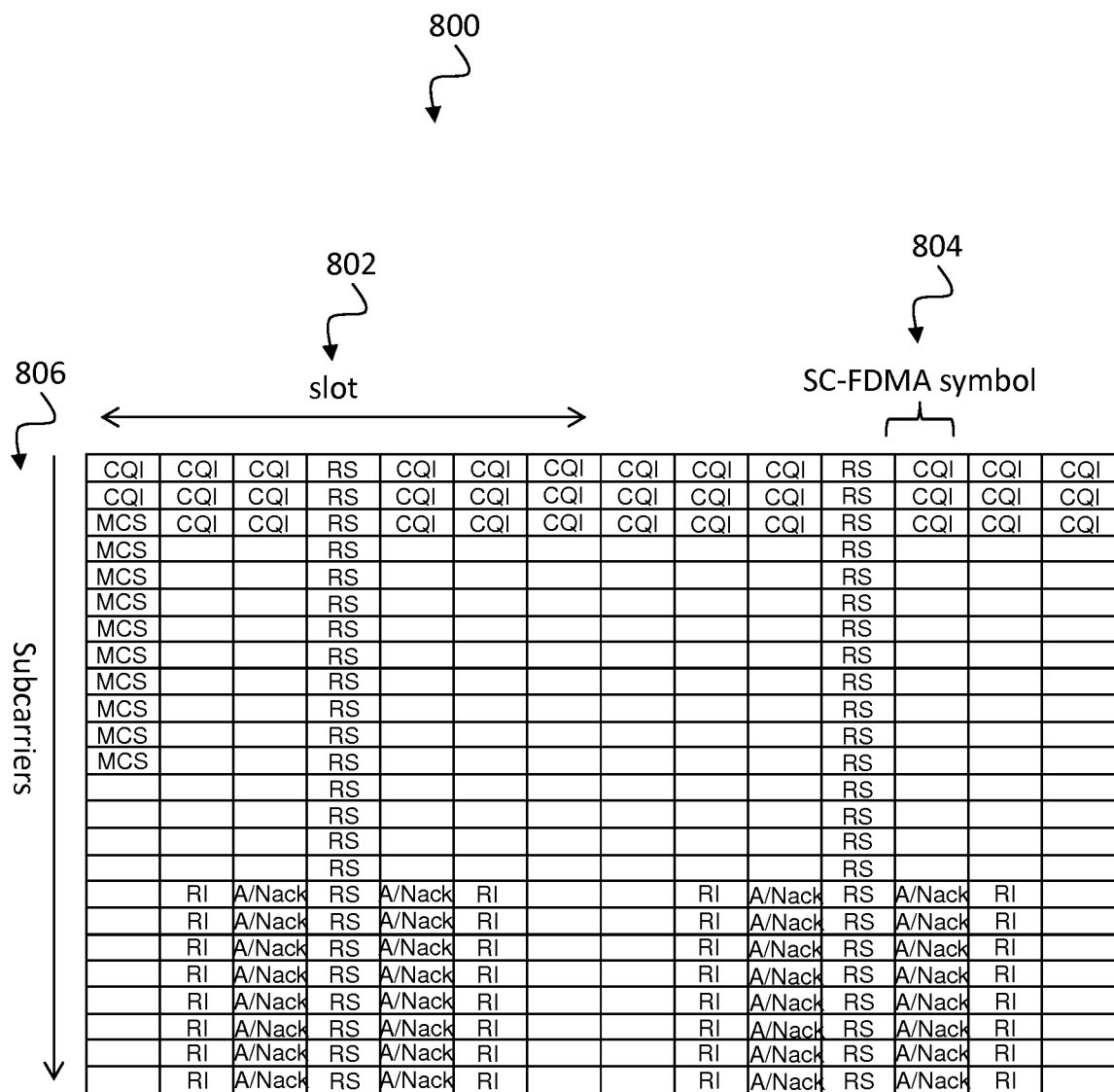


Fig. 8

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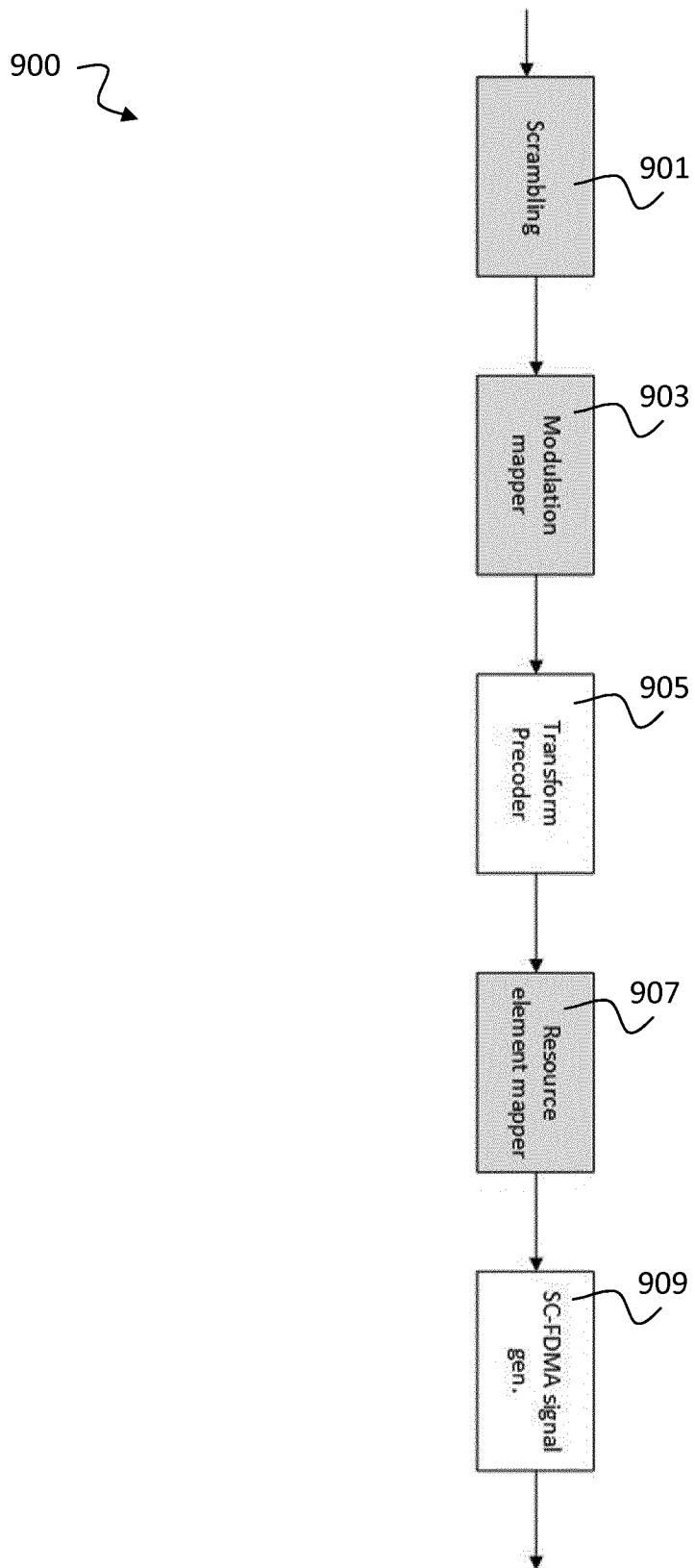


Fig. 9

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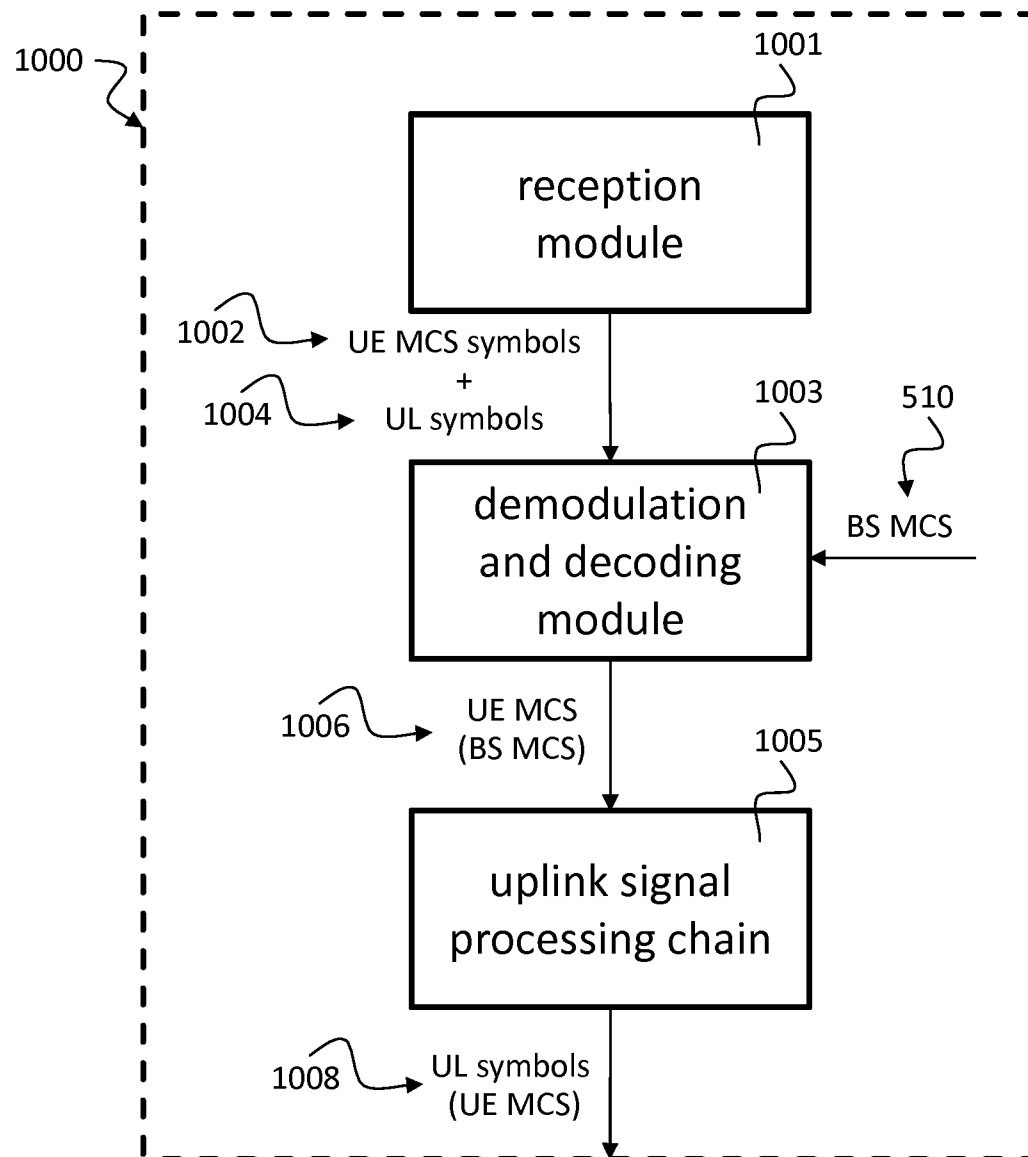


Fig. 10

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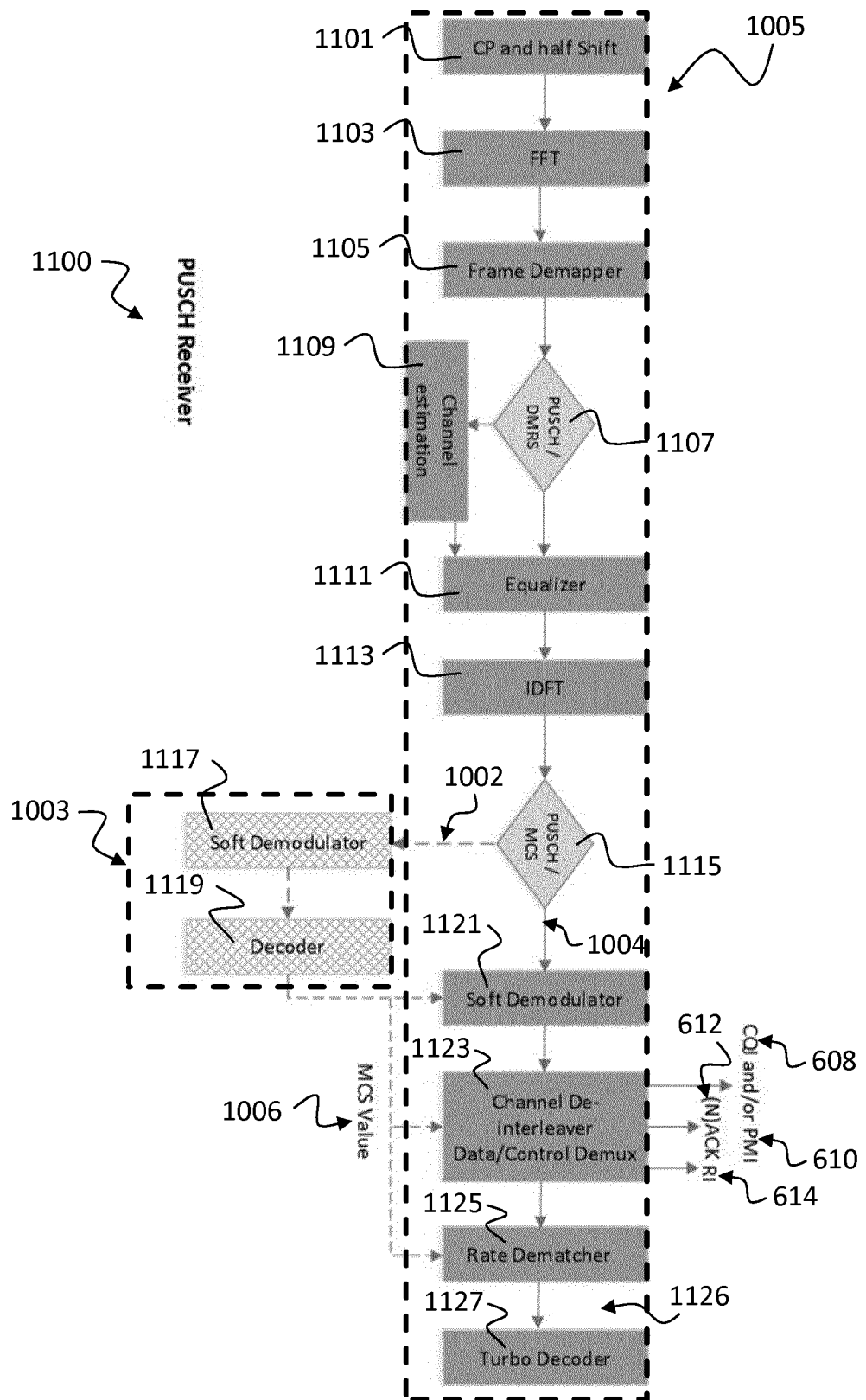


Fig. 11

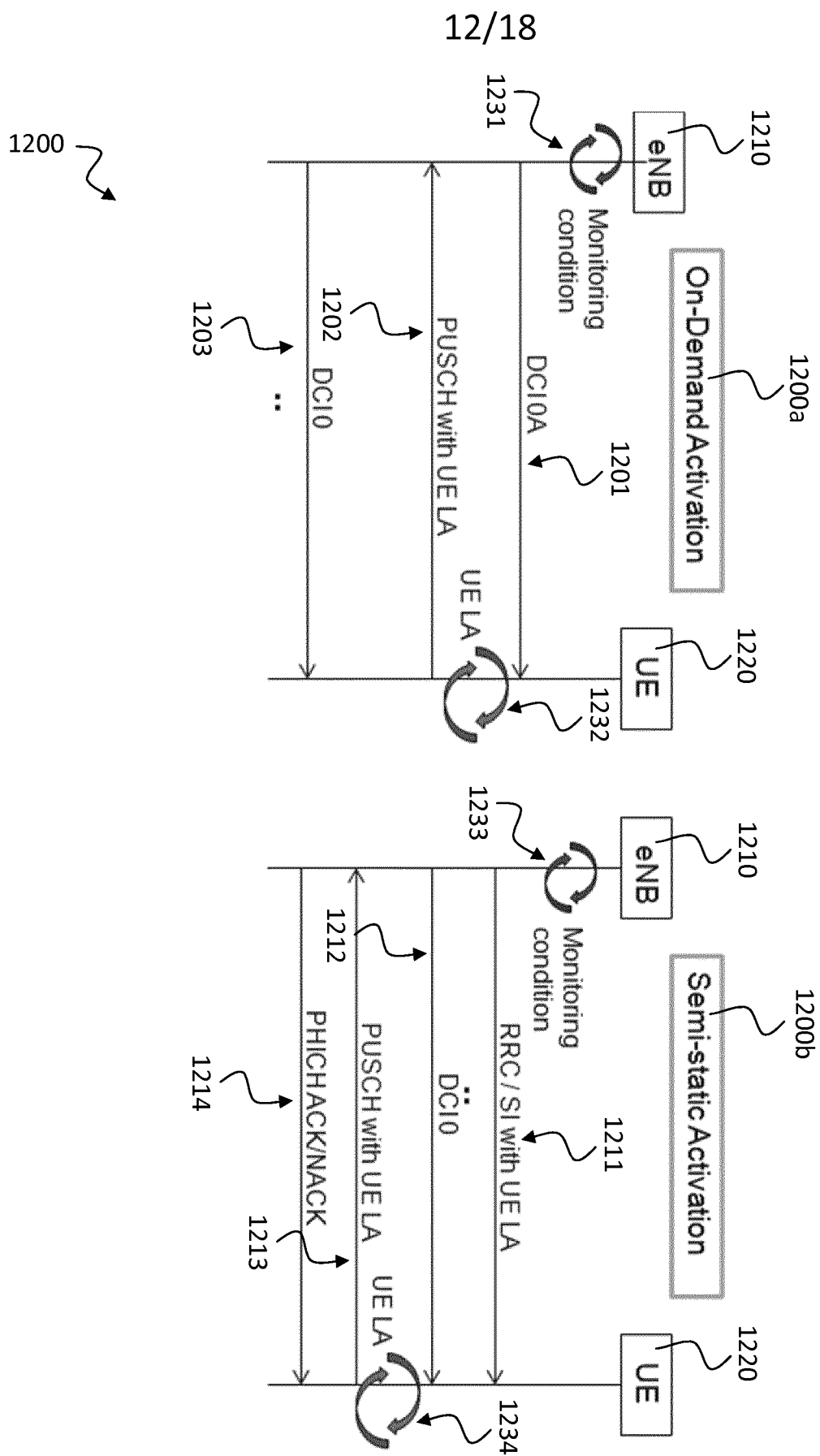


Fig. 12

DCI Format	DCI Contents	Size	Description
Format 0	DCI Format	-	Format 0
	FreqHopping	1-bit	PUSCH frequency hopping flag
	Allocation	variable	Resource block assignment/allocation
	Modcoding	5-bits	Modulation, coding scheme and redundancy version
	NewData	1-bit	New data indicator
	TPC	2-bits	PUSCH TPC command
	CSHiftDMRS	3-bits	Cyclic shift for DM RS
	CQIReq	1-bit	CQI request
	TDDIndex	2-bits	For TDD config 0, this field is the Uplink Index. For TDD config 1-6, this field is the Downlink Assignment Index.
			Not present for FDD.

Optional in modified DCI Format 0A

Fig. 13

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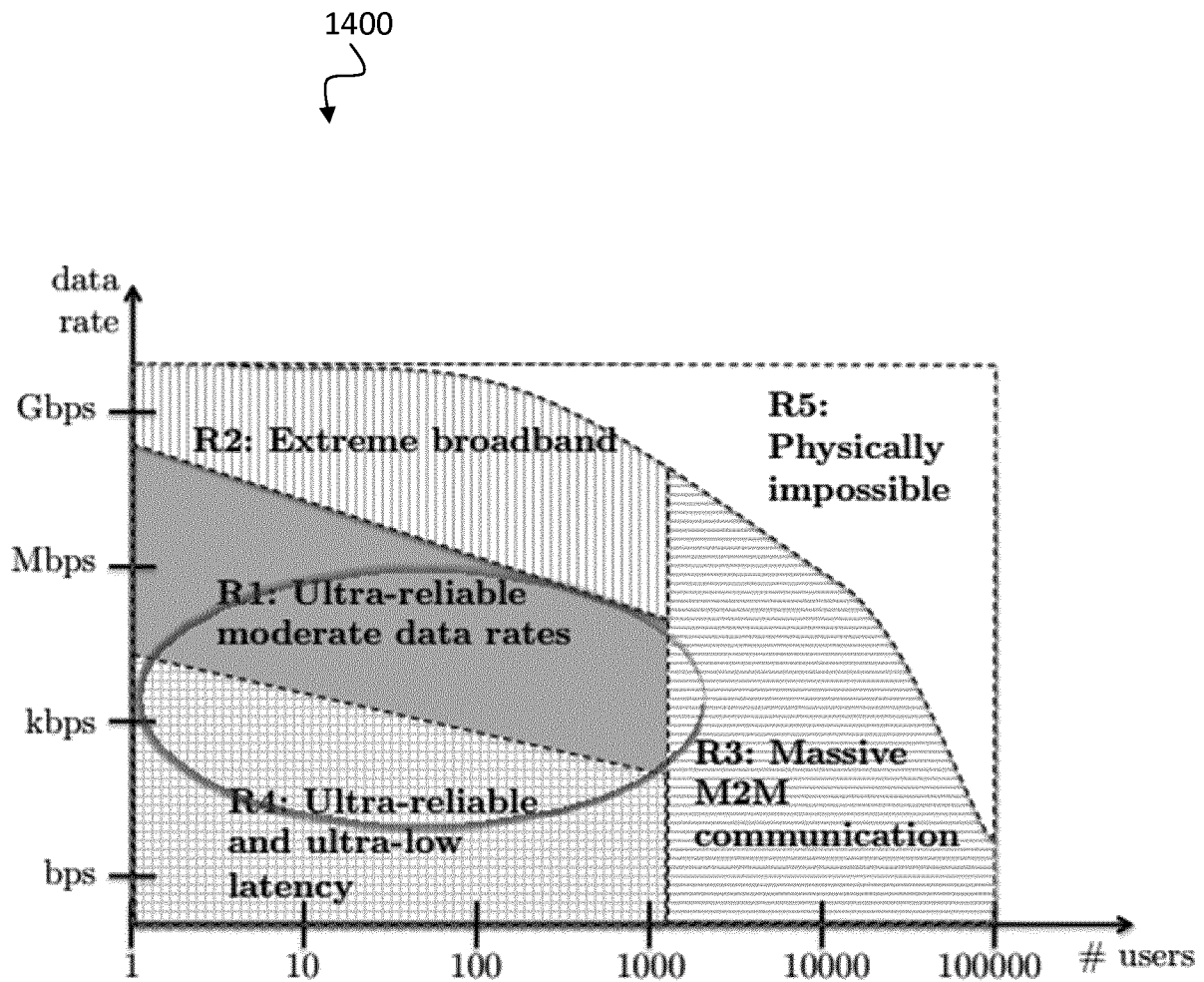


Fig. 14

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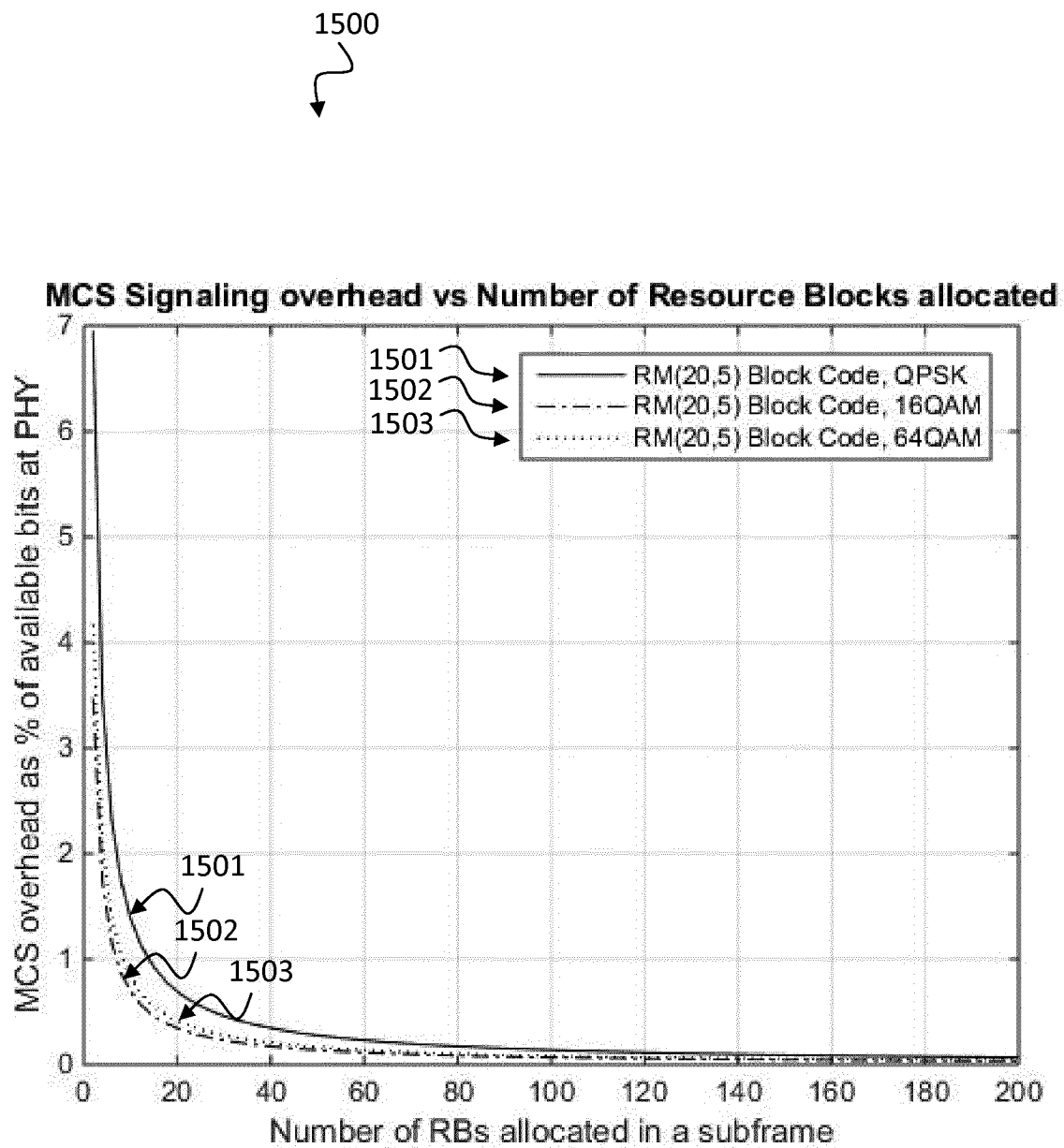


Fig. 15

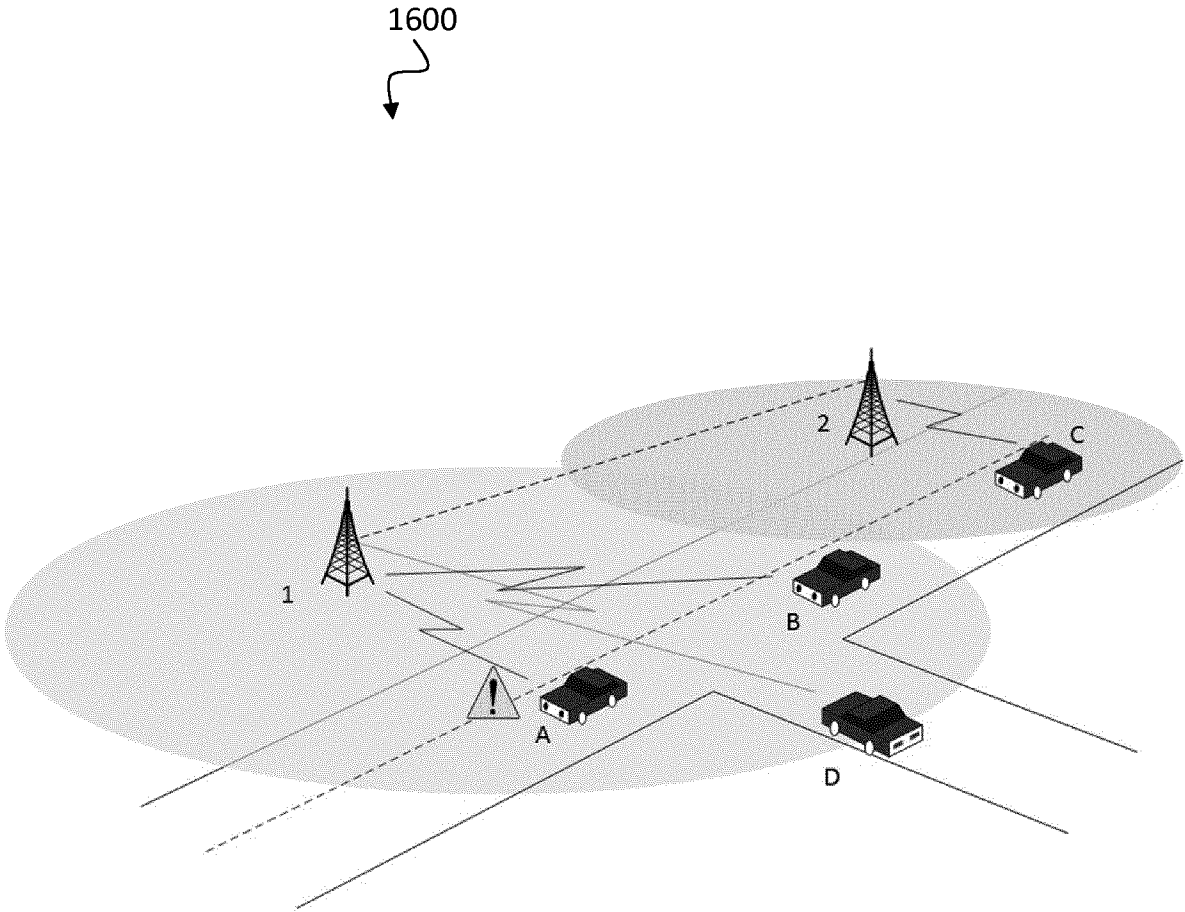


Fig. 16

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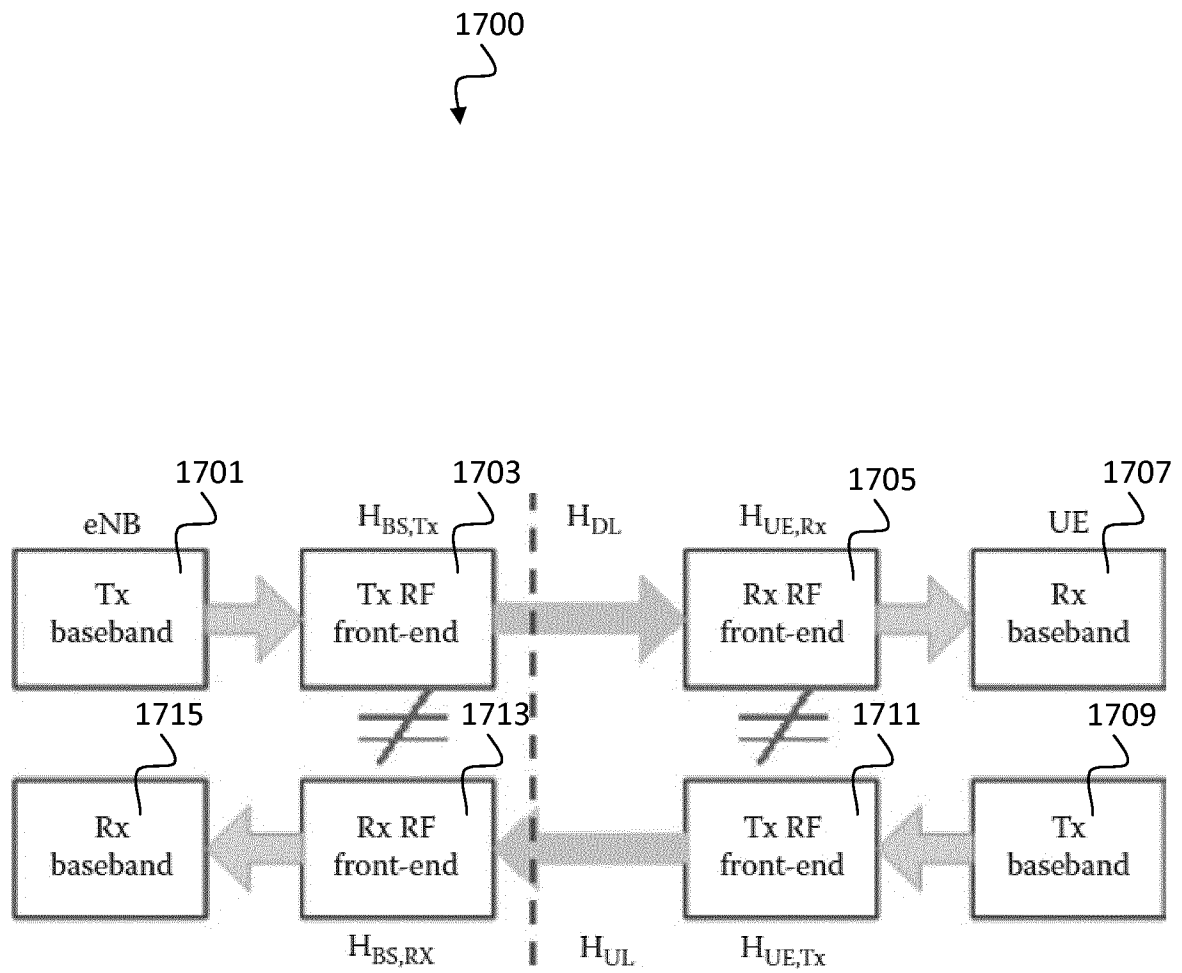


Fig. 17

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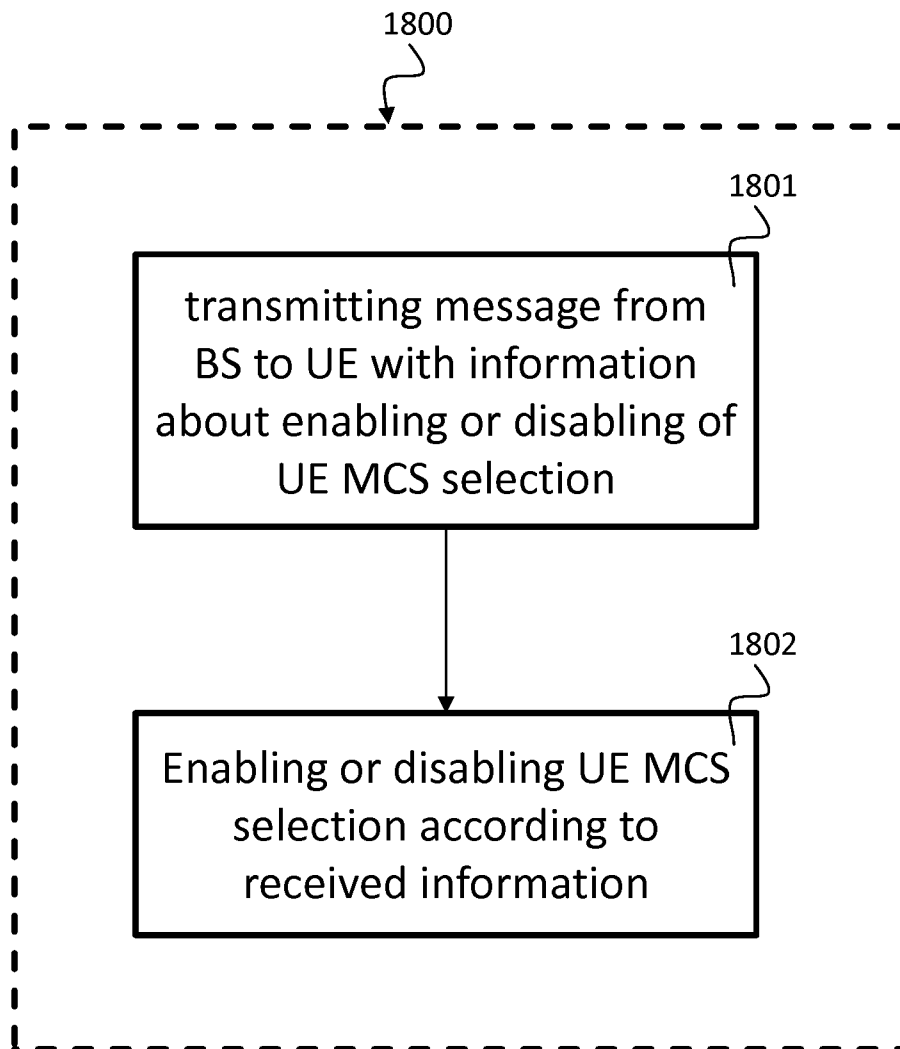


Fig. 18

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/053190A. 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 2010/303096 A1 (KASHER ASSAF [IL] ET AL) 2 December 2010 (2010-12-02) page 4, left-hand column, paragraph 34 - right-hand column, paragraph 38; figures 1,3 ----- -/--	1-16



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

2 November 2016

Date of mailing of the international search report

16/11/2016

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
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Authorized officer

Courville, Nicolas

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/053190

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	INTEL CORPORATION: "Introduction of the Non-Scheduled UL Operation for eLAA", 3GPP DRAFT; R1-160428, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. St. Julian's, Malta; 20160215 - 20160219 14 February 2016 (2016-02-14), XP051053765, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/RAN1/Docs/ [retrieved on 2016-02-14] Section 2 bridging pages 1 and 2 -----	1-16
A	"3rd Generation Partnership Project; Technical Specification Group GSM/EDGE Radio Access Network; General Packet Radio Service (GPRS); Overall description of the GPRS radio interface; Stage 2 (Release 13)", 3GPP STANDARD; 3GPP TS 43.064, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, vol. GERAN WG1, no. V13.0.0, 3 December 2015 (2015-12-03), pages 1-113, XP051046551, [retrieved on 2015-12-03] page 40 page 45 -----	1-16

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2016/053190

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		WO 2010141161 A2	09-12-2010
