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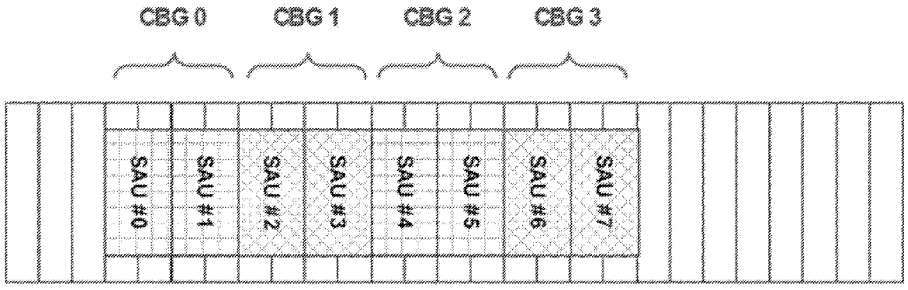

Figure 4. Illustration of a symbol alignment unit in time domain resource allocation

Figure 4

(57) **Abstract:** Systems, apparatuses, methods, and computer-readable media are provided for scheduling data transmissions with support for symbol alignment and/or early termination. The data transmissions may be above 52.6 GHz carrier frequency. Additionally, embodiments provide techniques for control channel transmission for slot-less operation. Other embodiments may be described and/or claimed.

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TECHNIQUES FOR CONTROL CHANNEL TRANSMISSION FOR SLOT-LESS OPERATION AND SCHEDULING DATA TRANSMISSIONS

CROSS REFERENCE TO RELATED APPLICATION

The present application claims priority to U.S. Provisional Patent Application No. 63/051,561, which was filed July 14, 2020 and International Application No. PCT/CN2020/103528, which was filed July 22, 2020.

FIELD

Various embodiments generally may relate to the field of wireless communications.

BACKGROUND

Mobile communication has evolved significantly from early voice systems to today's highly sophisticated integrated communication platform. The next generation wireless communication system, 5G, or new radio (NR) will provide access to information and sharing of data anywhere, anytime by various users and applications. NR is expected to be a unified network/system that targets to meet vastly different and sometime conflicting performance dimensions and services. Such diverse multi-dimensional requirements are driven by different services and applications. In general, NR will evolve based on 3GPP LTE-Advanced with additional potential new Radio Access Technologies (RATs) to enrich people lives with better, simple and seamless wireless connectivity solutions. NR will enable everything connected by wireless and deliver fast, rich content and services.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 illustrates an example of long physical downlink shared channel (PDSCH) transmission duration, in accordance with various embodiments.

Figure 2 illustrates an example of early termination of PDSCH transmission, in accordance with various embodiments.

Figure 3 illustrates an example of code block (CB) to time/frequency resource mapping in accordance with various embodiments.

Figure 4 illustrates a symbol alignment unit (SAU) in time domain resource allocation, in accordance with various embodiments.

Figure 5 illustrates a single transport block (TB) scheduled with multiple code block groups (CBGs) by a downlink control information (DCI), in accordance with various embodiments.

Figure 6 illustrates a single TB scheduled with multiple SAUs by a DCI, in accordance with various embodiments.

Figure 7 illustrates a single TB scheduled with multiple CBGs by a DCI, in accordance with various embodiments.

Figure 8 illustrates an example of two TBs scheduled with multiple SAUs by a DCI, in accordance with various embodiments.

Figure 9 illustrates another example of two TBs scheduled with multiple SAUs by a DCI, in accordance with various embodiments.

Figure 10 illustrates an example of two TBs scheduled with multiple CBGs by a DCI, in accordance with various embodiments.

Figure 11 illustrates another example of two TBs scheduled with multiple CBGs by a DCI, in accordance with various embodiments.

Figure 12 illustrates PDSCH scheduling with flexible duration and pre-determined physical downlink control channel (PDCCH) monitoring occasions, in accordance with various embodiments.

Figure 13 illustrates PDSCH scheduling with flexible duration and new PDCCH monitoring after PDSCH, in accordance with various embodiments.

Figure 14 illustrates PDSCH scheduling with flexible duration and new PDCCH monitoring in X symbols after PDSCH, in accordance with various embodiments.

Figure 15 illustrates a network in accordance with various embodiments.

Figure 16 schematically illustrates a wireless network in accordance with various embodiments.

Figure 17 is a block diagram illustrating components, according to some example embodiments, able to read instructions from a machine-readable or computer-readable medium (e.g., a non-transitory machine-readable storage medium) and perform any one or more of the methodologies discussed herein.

Figures 18-23 illustrate example procedures for practicing the various embodiments discussed herein.

DETAILED DESCRIPTION

The following detailed description refers to the accompanying drawings. The same reference numbers may be used in different drawings to identify the same or similar elements. In the following description, for purposes of explanation and not limitation, specific details are set forth such as particular structures, architectures, interfaces, techniques, etc. in order to provide a thorough understanding of the various aspects of various embodiments. However, it will be apparent to those skilled in the art having the benefit of the present disclosure that the various aspects of the various embodiments may be practiced in

other examples that depart from these specific details. In certain instances, descriptions of well-known devices, circuits, and methods are omitted so as not to obscure the description of the various embodiments with unnecessary detail. For the purposes of the present document, the phrase "A or B" means (A), (B), or (A and B).

Various embodiments herein include techniques to be implemented in a wireless cellular network. For example, embodiments include techniques for scheduling data transmissions for above 52.6 GHz carrier frequency. Additionally, embodiments include techniques for control channel transmission for slot-less operation.

SCHEDULING DATA TRANSMISSIONS FOR ABOVE 52.6GHZ CARRIER FREQUENCY

For a system operating above 52.6GHz carrier frequency, especially for Terahertz communication, it is envisioned that a larger subcarrier spacing is needed to combat severe phase noise. In case when a larger subcarrier spacing, e.g., 1.92MHz or 3.84MHz is employed, the slot duration can be very short. For instance, for 1.92MHz subcarrier spacing, one slot duration is approximately 7.8μs. This extremely short slot duration may not be sufficient for higher layer processing, including Medium Access Layer (MAC) and Radio Link Control (RLC), etc. In order to address this issue, next generation NodeB (gNB) may schedule the downlink (DL) or uplink (UL) data transmission across slot boundary with long transmission duration. In other words, slot concept may not be needed when scheduling data transmission. Figure 1 illustrates one example of long physical downlink shared channel (PDSCH) transmission duration.

In DL transmission, more DL traffic may arrive at the gNB when the gNB has already sent out a DL downlink control information (DCI) or a previous PDSCH transmission is still ongoing. The gNB has to send a new DL DCI to schedule a PDSCH which results in the delay of data transmissions. One solution could be to allow a gNB to schedule more DL resources than that required to transmit the current DL data in the buffer. Consequently, if new DL traffic arrives, gNB can continue the PDSCH transmission for the new DL traffic on the scheduled DL resource. On the other hand, if there is no new incoming DL traffic, the scheduled DL resources need to be released earlier, e.g. early termination of the PDSCH transmission. In fact, besides the case of lacking new DL traffic, there may also exist other reasons that gNB needs to terminate a DL transmission earlier. Figure 2 illustrates an example for which the allocated DL resources could carry 10 CBs. However, the DL transmission may be terminated only after the transmission of 6 CBs.

In existing NR code block (CB) to time/frequency resource mapping, there is no specific consideration on the symbols that are used to carry a CB or a CB group (CBG). As a result, different number of symbols may be occupied for different CBs or CBGs. Further, a CB tends to be split to multiple symbols. Such irregular mapping between CB and the symbols results in a varying time needed in the pipelined receive (Rx) processing to decode different CBs of a transport block (TB).

On the other hand, certain CBs may require a longer waiting time. For example, in Figure 3, there is one symbol gap between processing start of CB#1 and CB#2, but there is a two-symbol gap between processing start of CB#2 and CB#3. Irregular stalls in the Rx processing pipeline may result in inefficiency and larger latency which is undesirable for future application of 5G and 6G communication systems.

Various embodiments herein provide techniques for scheduling physical shared channel transmission to allow efficient symbol alignment and early termination operation. For example, detailed techniques are described herein to schedule a data transmission which supports symbol alignment and early termination for above 52.6GHz carrier frequency.

For the DL or UL transmission, a TB from MAC layer is transmitted at physical layer. For the hybrid automatic repeat request (HARQ) transmission of DL transmission, a single HARQ-ACK bit may be reported by UE for a TB. Alternatively, if code block group (CBG) based transmission is configured, e.g. a TB is divided into n CBGs, $n \leq N$, a CBG consists of one or multiple code block (CB)s. A UE may report n or N HARQ-ACK bits for the TB. One HARQ-ACK bit is reported for each CBG. N is the maximum number of CBGs which may be configured by high layer. A CBG may be mapped to all time/frequency resources of certain consecutive symbols, e.g. symbol alignment is achieved for a CBG.

Alternatively, every group of X CBs may be mapped to all time/frequency resources of Y consecutive symbols. In some embodiments, X may be relatively prime to Y. The set of Y consecutive symbols in resource allocation is the symbol alignment unit (SAU). A CBG could be mapped to a SAU. Alternatively, a CBG may be mapped to one or multiple SAUs. Alternatively, a SAU may consist of one or multiple CBGs. One HARQ-ACK bit may be reported for each CBG.

Figure 4 illustrates the use of SAU for symbol alignment. In this example, each SAU is mapped to all time/frequency resources of 2 symbols. The TB scheduled by a DCI is divided into 4 CBGs, and each CBG consists of 2 SAUs.

Start and length indicator *SLIV*

In existing NR system, the time domain resource allocation (TDRA) of a TB is indicated in a DCI. A row of the TDRA table indicates the starting symbol *S* relative to the start of the slot, and the number of consecutive symbols *L* counting from the symbol *S* allocated for the PDSCH or physical uplink shared channel (PUSCH), e.g. the start and length indicator (*SLIV*). By this scheme, a TB is mapped to L symbols, but it does not guarantee that any CB or CBG can end at the boundary of a symbol. The time domain resource allocation may be specifically designed to facilitate symbol alignment. In this case, the number of CBGs per TB may be configured by high layer signaling, indicated through DCI, or may be derived by the maximum length and the number of symbols for a CBG.

In one option, *SLIV* in the DCI indicates the specific time resource used by a CBG. The size of a CBG could be determined by the modulation and coding scheme (MCS), *L* indicated by *SLIV* and frequency resource allocation, if applicable. By this scheme, it is guaranteed that a CBG mapped to a number of consecutive symbols.

In another option, *SLIV* in the DCI indicates the time resource used by a SAU. The number of bits that are transmitted on a SAU may be determined by the MCS, *L* indicated by *SLIV* and frequency resource allocation, if applicable. The consecutive symbols in a SAU carry one or multiple CBs. For this option, given the SLIV indication, the association between SAU and CBG (e.g., how many CBG are mapped in a SAU or how many SAU form a CBG) may be indicated separately within the DCI, may be configured via radio resource control (RRC) signaling, or may be fixed for a specific subcarrier spacing.

Granularity for early termination

To support early termination of a PDSCH or PUSCH transmission, the granularity of early termination may be determined.

In one option, early termination is supported at the end of the transmission of each TB or every N TBs, where N is larger than 1. Alternatively, early termination is not allowed for the first X TBs, and early termination is allowed in every Y TBs after the first X TBs. X and Y are predefined or configured by high layer. Note that this may apply for the case of multi-TB based scheduling, where a single DCI is used to schedule one or more PDSCHs or PUSCHs.

In one option, early termination is supported at the end of the transmission of each CBG or every N CBGs, where N is larger than 1. Alternatively, early termination is not allowed for the first X CBGs, and early termination is allowed in every Y CBGs after the first X CBGs. $X \geq 1, Y \geq 1$. X and Y are predefined or configured by high layer. Note that this may apply

for the case of single-TB based scheduling, where a single DCI is used to schedule one PDSCH or PUSCH, and the PDSCH or PUSCH consists of one or more CBs/CBGs.

In one option, early termination is supported at the end of the transmission of each SAU or every N SAUs, where N is larger than 1. Alternatively, early termination is not allowed for the first X SAUs, and early termination is allowed in every Y SAUs after the first X SAUs. $X \geq 1, Y \geq 1$. X and Y may be predefined or configured by high layer.

In one option, early termination is not allowed for the first X TBs, and early termination is allowed in every Y CBGs after the first X TBs. $X \geq 1, Y \geq 1$. X and Y may be predefined or configured by high layer.

In one option, early termination is not allowed for the first X TBs, and early termination is allowed in every Y SAUs after the first X TBs. $X \geq 1, Y \geq 1$. X and Y may be predefined or configured by high layer.

Single TB scheduling by a DCI

Embodiments for the case of single TB based transmission scheduled by a DCI are provided as follows.

In one embodiment, a DCI may schedule a PDSCH or a PUSCH which carries only one TB. The TB is segmented into multiple CBGs. Each CBG includes one or multiple CBs. Symbol alignment is achieved for each CBG. In this case, the *SLIV* in the DCI may indicate the time resource of a CBG. The maximum number of CBGs of the TB may be configured by high layer signaling. In alternative, the maximum length of the allocated time resource for a PDSCH or a PUSCH is configured, so that the number of CBGs of the TB can be derived by the maximum length and the number of symbols for a CBG. Alternatively, the maximum number of CBGs of the current TB may be indicated in DCI dynamically or a combination of RRC signaling and dynamic indication by DCI. The transmission of the PDSCH or PUSCH can be terminated at the symbol boundary of a CBG.

Figure 5 illustrates the case of a single TB scheduled with multiple CBGs by a DCI. In this case, the *SLIV* indicates the time resource of a CBG, e.g. each CBG is mapped to all time/frequency resources of 4 symbols. Therefore, symbol alignment is achieved for a CBG. For example, if the last CBG is not transmitted due to early termination, the TB only consists of 3 valid CBGs. However, UE may still need to report 4 HARQ-ACK bits for the TB to have a constant payload size of HARQ-ACK.

In one option, for the HARQ-ACK feedback, a UE may generate one HARQ-ACK bit for each CBG. To schedule a retransmission of the corresponding TB, CBG transmission indicator (CBGTI) may be used to indicate retransmission or not for each CBG. For example, if k^{th} bit of CBGTI is '1', retransmission of the kth CBG is scheduled.

In another option, if the maximum number of CBGs is large, e.g. more than 8, the overhead of CBGTI is quite high in a DCI. In this case, CBG based HARQ-ACK feedback may not be used. That is, only one HARQ-ACK bit is reported for the TB. Within the DCI triggering retransmission of the TB, the actual number of CBGs that are transmitted by the gNB may be indicated. For example, denote the maximum number of CBGs as N, the field indicating the actual number of transmitted CBG can have a size of $\lceil log_2(N) \rceil$. By this way, the UE may know the correct number of transmitted CBGs even when the UE fails to detect the correct number of transmitted CBGs in the early transmissions.

In another option, HARQ-ACK bundling of CBGs may be supported to limit the number of HARQ-ACK bits. For example, the maximum number of HARQ-ACK bits per TB may be 8. The number of CBGs mapped to a HARQ-ACK bit may be predefined or configured by high layer. Alternatively, the number of CBGs mapped to a HARQ-ACK bit may be dynamically indicated in the DCI or a combination of RRC signaling and dynamic indication by DCI. The last HARQ-ACK bit before termination of the transmission may have a smaller number of CBGs. Denote the maximum number of CBGs as N, maximum number of HARQ-ACK bits per TB is M, the N CBGs are mapped to the M HARQ-ACK bits. In case, the N CBGs cannot be evenly grouped and mapped to M HARQ-ACK bits, the last group(s) may be composed by a slightly lower or larger number of CBGs. The evenly distributed CBGs, if present, may be mapped to the same HARQ-ACK bit, e.g. CBG n is mapped to HARQ-ACK bit $b_n = mod(n, M), n = 0,1, \dots, N-1$. Alternatively, the consecutive CBGs, if present, may be mapped to the same HARQ-ACK bit, e.g. CBG n is mapped to HARQ-ACK bit $b_n = \begin{cases} floor\left(n/\left\lceil \frac{N}{M} \right\rceil\right) & n < mod(N,M) \cdot \left\lceil \frac{N}{M} \right\rceil \\ floor\left((n - mod(N,M))/\left\lfloor \frac{N}{M} \right\rfloor\right) & otherwise \end{cases}$.

In one embodiment, a DCI can schedule a PDSCH or a PUSCH which carries only one TB. The TB is segmented into multiple SAUs. Each SAU includes one or multiple CBs. Symbol alignment is achieved for each SAU. In this case, the *SLIV* in the DCI may indicate the time resource of a SAU. The maximum number of SAU of the TB may be configured by high layer signaling. As one alternative, the maximum length of the allocated time resource for a

PDSCH or a PUSCH is configured, so that the number of SAU of the TB can be derived by the maximum length and the number of symbols for a SAU. As an additional alternative, the maximum number of SAUs of the current TB may be indicated in DCI dynamically or a combination of RRC signalling and dynamic indication by DCI. The transmission of the PDSCH or PUSCH can be terminated at the symbol boundary of a SAU.

One or more SAU may be grouped into a CBG. The number of SAUs for a CBG may be predefined or configured by high layer. Alternatively, the number of SAUs for a CBG may be dynamically indicated in the DCI or a combination of RRC signaling and dynamic indication by DCI. The last CBG before termination of the transmission may have a smaller number of SAUs. Alternatively, the SAU(s) that compose a CBG may be determined by the total number of SAUs and the number of CBGs.

Denote the maximum number of SAU as N, the maximum number of CBG, e.g. maximum number of HARQ-ACK bits per TB is M, the N SAUs are mapped to the M CBGs. In case, the N SAUs cannot be evenly grouped into M CBGs, the last CBG(s) may be composed by a slightly lower or larger number of SAUs. The evenly distributed SAUs, if present, may be mapped to the same CBG, e.g. SAU n is mapped CBG $b_n = mod(n, M), n = 0,1, \dots, N-1$. Alternatively, the consecutive SAUs, if present, may be mapped to the same CBG, e.g. SAU n is mapped CBG $b_n = \begin{cases} floor\left(n/\left\lceil\frac{N}{M}\right\rceil\right) & n < mod(N,M)\cdot\left\lceil\frac{N}{M}\right\rceil \\ floor\left(\left(n - mod(N,M)\right)/\left\lfloor\frac{N}{M}\right\rfloor\right) & otherwise \end{cases}$.

Figure 6 illustrates the case of a single TB scheduled with multiple CBGs by a DCI. In this case the *SLIV* indicates the time resource of a SAU, e.g. each SAU is mapped to all time/frequency resources of 2 symbols. Therefore, symbol alignment is achieved for a SAU. Each CBG consists of 2 consecutive SAUs. For example, if the last 2 SAUs are not transmitted due to early termination, the TB only consists of 3 valid CBGs. However, UE may still need to report 4 HARQ-ACK bits for the TB to have a constant payload size of HARQ-ACK.

Figure 7 illustrates the case of a single TB scheduled with multiple CBGs by a DCI. In this case, the *SLIV* indicates the time resource of a SAU, e.g. each SAU is mapped to all time/frequency resources of 2 symbols. Therefore, symbol alignment is achieved for a SAU. CBG k consists of 2 SAUs with index k and k+4. For example, if the last 2 SAUs are not transmitted due to early termination, the TB still consists of 4 CBGs. Each CBG has a reduced CBG size. However, the last 2 CBGs has only one CBG respectively. The 4 HARQ-ACK bits reported bits are all useful indication for the four CBGs.

For the HARQ-ACK feedback, UE may generate one HARQ-ACK for each CBG. By this way, the number of HARQ-ACK bits reported per TB can be limited. For example, the maximum number of HARQ-ACK bits per TB is 8. To schedule a retransmission of the TB, CBG transmission indicator (CBGTI) may be used to indicate retransmission or not for each CBG. For example, if the kth bit of CBGTI is '1', retransmission of the kth CBG is scheduled.

Multiple TB scheduling without CBG by a DCI

A DCI may schedule a transmission to carry one or multiple TBs. However, it may be assumed that CBG-based transmission may not be supported or configured.

For the HARQ-ACK feedback, UE may generate one HARQ-ACK for each TB. Alternatively, HARQ-ACK bundling of TBs may be used to limit the number of HARQ-ACK bits. For example, the maximum number of HARQ-ACK bits per TB is 8. Denote the maximum number of TBs as N, maximum number of HARQ-ACK bits per TB is M, the N TBs are mapped to the M HARQ-ACK bits. In case, the N TBs cannot be evenly grouped and mapped to M HARQ-ACK bits, the last group(s) may be composed by a slightly lower or larger number of TBs. The evenly distributed TBs, if present, may be mapped to the same HARQ-ACK bit, e.g. TB n is mapped to HARQ-ACK bit $b_n = mod(n, M), n = 0,1, \dots, N-1$. Alternatively, the consecutive TBs, if present, may be mapped to the same HARQ-ACK bit, e.g. TB n is mapped to HARQ-ACK bit $b_n = \begin{cases} floor\left(n/\left\lceil\frac{N}{M}\right\rceil\right) & n < mod(N,M)\cdot\left\lceil\frac{N}{M}\right\rceil \\ floor\left(\left(n - mod(N,M)\right)/\left\lfloor\frac{N}{M}\right\rfloor\right) & otherwise \end{cases}$.

The number of NDI/RV bits in the DCI is equal to the maximum number of TBs scheduled by the DCI. The HARQ process number indicated by the DCI may apply to the first scheduled TB by the DCI, while the consecutive HARQ process number after the indicated HARQ process number is used in other scheduled TBs by the DCI.

In one embodiment, symbol alignment is achieved for each TB. In this case, the *SLIV* in the DCI may indicate the time resource of a TB. The maximum number of TBs of the transmission may be configured by high layer signaling. Or, the maximum length of the allocated time resource for a PDSCH or a PUSCH is configured, so that the maximum number of TBs of the transmission can be derived by the maximum length and the number of symbols for a TB. Alternatively, the maximum number of TBs of the current transmission may be indicated in DCI dynamically or a combination of RRC signaling and dynamic indication by

DCI. The transmission of the PDSCH or PUSCH can be terminated at the symbol boundary of a TB.

In one embodiment, symbol alignment is achieved for each SAU. *SLIV* in the DCI may indicate the time resource of a SAU. The maximum number of SAU of the transmission may be configured by high layer signaling. Or, the maximum length of the allocated time resource for a PDSCH or a PUSCH is configured, so that the number of SAU can be derived by the maximum length and the number of symbols in a SAU. Alternatively, the maximum number of SAUs of the current transmission may be indicated in the DCI dynamically or a combination of RRC signaling and dynamic indication by DCI. The transmission of the PDSCH or PUSCH can be terminated at the symbol boundary of a SAU.

One or more SAU can be grouped into a TB. The number of SAUs for a TB may be predefined or configured by high layer. Alternatively, the number of SAUs for a TB may be dynamically indicated in the DCI. The last TB before termination of the transmission may have a smaller number of SAUs. Alternatively, the SAU(s) that are included in a TB may be determined by the number of SAUs and the number of TBs. Denote the maximum number of SAU as N, maximum number of TB, e.g. maximum number of HARQ-ACK bits per transmission is M, the N SAUs are mapped to the M TBs. In case, the N SAUs cannot be evenly grouped into M TBs, the last TB(s) may be composed by a slightly lower or larger number of SAUs. The consecutive SAUs, if present, may be mapped to the same TB, e.g. SAU n is mapped TB $b_n = \begin{cases} floor\left(n/\left\lceil\frac{N}{M}\right\rceil\right) & n < mod(N,M)\cdot\left\lceil\frac{N}{M}\right\rceil \\ floor\left(\left(n-mod(N,M)\right)/\left\lfloor\frac{N}{M}\right\rfloor\right) & otherwise \end{cases}$. Alternatively, the evenly distributed SAUs, if present, may be mapped to the same TB, e.g. SAU n is mapped TB $b_n = mod(n,M), n = 0,1,\ldots,N-1$.

Figure 8 illustrates an example of scheduling two TBs by a DCI. In this case, the *SLIV* indicates the time resource of a SAU, e.g. each SAU is mapped to all time/frequency resources of 2 symbols. Therefore, symbol alignment is achieved for a SAU. Each CBG consists of 4 consecutive SAUs. For example, if the last 4 SAUs are not transmitted due to early termination, there is only one TB transmitted in the current transmission. However, UE may still need to report 2 HARQ-ACK bits for two TBs to have a constant payload size of HARQ-ACK.

Figure 9 illustrates another example of scheduling of two TBs by a DCI. In this case, the *SLIV* indicates the time resource of a SAU, e.g. each SAU is mapped to all time/frequency resources of 2 symbols. Therefore, symbol alignment is achieved for a SAU. TB k consists of 4 SAUs with index k, k+2, k+4, k+6. For example, if the last 4 SAUs are not transmitted due

to early termination, there are still two TBs transmitted in the current transmission. Each TB has a reduced TB size. The 2 HARQ-ACK bits reported bits are all useful indication for the 2 TBs.

Multiple TB scheduling with CBG by a DCI

A DCI can schedule a transmission which can carry one or multiple TBs. Further, it is assumed that CBG based transmission is also configured for each TB.

For the HARQ-ACK feedback, UE may generate one HARQ-ACK bit for each CBG. To schedule a retransmission of the TB, CBG transmission indicator (CBGTI) may be used to indicate retransmission or not for each CBG of a retransmitted TB. For example, if the kth bit of CBGTI is '1', retransmission of the kth CBG is scheduled.

The number of NDI/RV bits in the DCI equals to the maximum number of TBs scheduled by the DCI. HARQ process number indicated by the DCI may apply to the first scheduled TB by the DCI, while the consecutive HARQ process number after the indicated HARQ process number is used in other scheduled TBs by the DCI.

In one embodiment, symbol alignment is achieved for each TB. *SLIV* in the DCI may indicate the time resource of a TB. The maximum number of TBs of the transmission may be configured by high layer signaling. Or, the maximum length of the allocated time resource for a PDSCH or a PUSCH is configured, so that the maximum number of TBs of the transmission can be derived by the maximum length and the number of symbols for a TB. Alternatively, the maximum number of TBs of the current transmission may be indicated in DCI dynamically or a combination of RRC signalling and dynamic indication by DCI. The transmission of the PDSCH or PUSCH may be terminated at the symbol boundary of a TB.

In one embodiment, symbol alignment is achieved for each CBG. Each CBG includes one or multiple CBs. *SLIV* in the DCI may indicate the time resource of a CBG. The maximum number of CBGs of the transmission may be configured by high layer signaling. Or, the maximum length of the allocated time resource for a PDSCH or a PUSCH is configured, so that the maximum number of CBGs of the transmission can be derived by the maximum length and the number of symbols for a CBG. Alternatively, the maximum number of CBGs of the current transmission may be indicated in DCI dynamically or a combination of RRC signalling and dynamic indication by DCI. The transmission of the PDSCH or PUSCH may be terminated at the symbol boundary of a CBG.

One or more CBGs may be grouped into a TB. The number of CBGs for a TB may be predefined or configured by high layer. Alternatively, the number of CBGs for a TB may be

dynamically indicated in the DCI or a combination of RRC signalling and dynamic indication by DCI. The last TB before termination of the transmission may have a smaller number of CBGs. Alternatively, the CBG(s) that are included in a TB may be determined by the number of CBGs and the number of TBs. Denote the maximum number of CBGs as N, the maximum number of TBs is M, the N CBGs are mapped to the M TBs. In case, the N CBGs cannot be evenly grouped into M TBs, the last TB(s) may be composed by a slightly lower or larger number of CBGs. The evenly distributed CBGs, if present, may be mapped to the same TB, e.g. CBG n is mapped TB $b_n = mod(n, M), n = 0,1, \ldots, N-1$. Alternatively, the consecutive CBGs, if present, may be mapped to the same TB, e.g. CBG n is mapped TB $b_n = \begin{cases} floor\left(n/\left\lceil\frac{N}{M}\right\rceil\right) & n < mod(N,M)\cdot\left\lceil\frac{N}{M}\right\rceil \\ floor\left(\left(n - mod(N,M)\right)/\left\lfloor\frac{N}{M}\right\rfloor\right) & otherwise \end{cases}$.

Figure 10 illustrates an example of scheduling of two TBs by a DCI. In this case, the *SLIV* indicates the time resource of a CBG, e.g. each CBG is mapped to all time/frequency resources of 2 symbols. Therefore, symbol alignment is achieved for a CBG. Each TB consists of 4 consecutive CBGs. For example, if the last 4 CBGs are not transmitted due to early termination, there is only one TB transmitted in the current transmission. However, UE may still need to report 8 HARQ-ACK bits for two TBs to have a constant payload size of HARQ-ACK.

Figure 11 illustrates an example of scheduling of two TBs by a DCI. In this case, the *SLIV* indicates the time resource of a CBG, e.g. each CBG is mapped to all time/frequency resources of 2 symbols. Therefore, symbol alignment is achieved for a CBG. Each TB consists of 4 consecutive CBGs. TB k consists of 4 SAUs with index k, k+2, k+4, k+6. For example, if the last 4 CBGs are not transmitted due to early termination, there are still two TBs transmitted in the current transmission. Each TB has a reduced number of CBGs. However, UE may still need to report 8 HARQ-ACK bits for the two TBs to have a constant payload size of HARQ-ACK.

In one embodiment, symbol alignment is achieved for each SAU. *SLIV* in the DCI may indicate the time resource of a SAU. The maximum number of SAU of the transmission may be configured by high layer signaling. Or, the maximum length of the allocated time resource for a PDSCH or a PUSCH is configured, so that the maximum number of SAUs of the transmission can be derived by the maximum length and the number of symbols for a SAU. Alternatively, the maximum number of SAUs of the current transmission may be indicated in

the DCI dynamically or a combination of RRC signalling and dynamic indication by DCI. The transmission of the PDSCH or PUSCH may be terminated at the symbol boundary of a SAU.

One or more SAU can be grouped into a CBG. The number of SAUs for a CBG may be predefined or configured by high layer. Alternatively, the number of SAUs for a CBG may be dynamically indicated in the DCI. The last CBG before termination of the transmission may have a smaller number of SAUs. Alternatively, the SAU(s) that are included in a CBG may be determined by the number of SAUs and the number of CBGs. Denote the maximum number of SAU as N, the maximum number of CBG, e.g. maximum number of HARQ-ACK bits per TB is M, the N SAUs are mapped to the M CBGs. In case, the N SAUs cannot be evenly grouped into M CBGs, the last CBG(s) may be composed by a slightly lower or larger number of SAUs. The consecutive SAUs, if present, may be mapped to the same CBG, e.g. SAU n is mapped CBG $b_n = \begin{cases} floor\left(n/\left\lceil\frac{N}{M}\right\rceil\right) & n < mod(N,M)\cdot\left\lceil\frac{N}{M}\right\rceil \\ floor\left(\left(n-mod(N,M)\right)/\left\lfloor\frac{N}{M}\right\rfloor\right) & otherwise \end{cases}$.

Alternatively, the evenly distributed SAUs, if present, may be mapped to the same CBG, e.g. SAU n is mapped CBG $b_n = mod(n,M), n = 0,1,\dots,N-1$.

CONTROL CHANNEL TRANSMISSION FOR SLOT-LESS OPERATION

NR supports physical downlink control channel (PDCCH) that conveys scheduling decision for both DL and UL through DCI. PDCCH is sent over a control resource set (CORESET). CORESETs may be configured in units of six PRBs (e.g., with one PRB including 12 resource elements) in the frequency domain and one, two, or three consecutive orthogonal frequency-division multiplexing (OFDM) symbols in time domain. The corresponding parameters are configured for the UE using *frequencyDomainResources* and duration parameters. An example of a configuration for a control resource set is as follows:

```
ControlResourceSet ::=          SEQUENCE {
controlResourceSetId            ControlResourceSetId,

frequencyDomainResources        BIT STRING (SIZE (45)),
duration                        INTEGER (1..maxCoReSetDuration),
cce-REG-MappingType             CHOICE {
  interleaved                   SEQUENCE {
    reg-BundleSize              ENUMERATED {n2, n3, n6},
    interleaverSize             ENUMERATED {n2, n3, n6},
```

```
            shiftIndex                  INTEGER(0..maxNrofPhysicalResourceBlocks-1)
          },
          nonInterleaved                NULL
        },
        precoderGranularity             ENUMERATED {sameAsREG-bundle,
      allContiguousRBs},
        tci-StatesPDCCH-ToAddList       SEQUENCE(SIZE (1..maxNrofTCI-
      StatesPDCCH)) OF TCI-StateId
       NotSIB1-initialBWP
        tci-StatesPDCCH-ToReleaseList   SEQUENCE(SIZE (1..maxNrofTCI-
      StatesPDCCH)) OF TCI-StateId
       NotSIB1-initialBWP
        tci-PresentInDCI                ENUMERATED {enabled}
        pdcch-DMRS-ScramblingID         INTEGER (0..65535)
        ...,
        [[
        rb-Offset-r16                   INTEGER (0..5)
        tci-PresentInDCI-ForDCI-Format1-2-r16  INTEGER (1..3)
        coresetPoolIndex-r16            INTEGER (0..1)
        controlResourceSetId-r16        ControlResourceSetId-r16
        ]]
      }
```

In CORESET one resource element group (REG) may be made up of one resource block and one OFDM symbol in time domain. A Control Channel Element (CCE) may be made up of six REGs. The actual number of CCEs for a PDCCH is determined by PDCCH aggregation level. UE performs blind decoding of PDCCH for the specific set of CCEs denoted as search space (SS). 5G NR supports two SS set types: common SS (CSS) set, which is commonly monitored by a group of UEs in the cell, and UE-specific SS (USS) set, which is monitored by an individual UE.

UE-specific search space is configured by RRC. The monitored positions of PDCCH are defined by *monitoringSlotPeriodicityAndOffset* parameter conveying information on periodicity of monitoring as well as slot offset. An example search space configuration is as follows:

```
SearchSpace ::=                 SEQUENCE {
  searchSpaceId                   SearchSpaceId,
  controlResourceSetId              ControlResourceSetId
  monitoringSlotPperiodicityAndOffset     CHOICE {
    sl1                           NULL,
    sl2                           INTEGER (0..1),
    sl4                           INTEGER (0..3),
    sl5                           INTEGER (0..4),
    sl8                           INTEGER (0..7),
    sl10                          INTEGER (0..9),
    sl16                          INTEGER (0..15),
    sl20                          INTEGER (0..19),
    sl40                          INTEGER (0..39),
    sl80                          INTEGER (0..79),
    sl160                         INTEGER (0..159),
    sl320                         INTEGER (0..319),
    sl640                         INTEGER (0..639),
    sl1280                        INTEGER (0..1279),
    sl2560                        INTEGER (0..2559)
  }
  duration                        INTEGER (2..2559)
  monitoringSymbolsWithinSlot          BIT STRING (SIZE (14))
  nrofCandidates                  SEQUENCE {
    aggregationLevel1                 ENUMERATED {n0, n1, n2, n3, n4, n5, n6, n8},
    aggregationLevel2                 ENUMERATED {n0, n1, n2, n3, n4, n5, n6, n8},
    aggregationLevel4                 ENUMERATED {n0, n1, n2, n3, n4, n5, n6, n8},
    aggregationLevel8                 ENUMERATED {n0, n1, n2, n3, n4, n5, n6, n8},
    aggregationLevel16                ENUMERATED {n0, n1, n2, n3, n4, n5, n6, n8}
  }
...
}
```

NR supports conventional slot-level based scheduling denoted in 5G NR as Type A mapping. Slot-level transmission can only start at specific OFDM symbol, but has flexible duration up to 14 OFDM symbols within a slot. Type A mapping typically has relatively long transmission time interval, which helps to reduce the overhead from reference signals and control channel as well as to increase coverage. Conventional slot-level based scheduling, however, is not efficient for all deployment scenarios. For instance, for 5G NR operation in unlicensed spectrum (NR-U) it is necessary to start transmission as early as possible after Listen-Before-Talk (LBT). In the case of mmWave, high payload transmission can be already realized within a few OFDM symbols due to the use of large bandwidth sizes. Finally, in the case of low latency transmission required for time-critical data applications, it is beneficial to start the transmission at any OFDM symbol without constraints. To optimize the system performance for such deployment scenarios, 5G NR also supports mini-slot based transmission, denoted as Type B mapping, in addition to slot-based scheduling. Mini-slot based scheduling enables physical shared channel transmission to start at any OFDM symbol within a slot and to have flexible duration of two, four or seven OFDM symbols. To facilitate early decoding in mini-slot based scheduling, the control channel and reference signals are located at the beginning of the transmission.

To further provide flexibility to the scheduling procedure, future systems may support transmission with more flexible duration spanning large number of OFDM symbols spanning multiple slots. The actual duration of the transmission may be variable and not aligned with periodicity of PDCCH monitoring occasions. As a result, unused time gaps may occur between last symbol of PDSCH transmission and next PDCCH transmission opportunity. The problem is illustrated in Figure 12 in more details.

Accordingly, under prior schemes, the control channel transmission is only possible at specific location configured by RRC. For PDSCH transmission with more flexible duration unused time gaps may occur between last symbol of PDSCH transmission and next PDCCH transmission opportunity.

Various embodiments herein provide techniques for PDCCH transmission on a more dynamic time location relative to the scheduled PDSCH. Embodiments may be adopted into future specifications supporting flexible PDSCH transmission.

According to some embodiments, additional flexible PDCCH monitoring occasions may be defined from OFDM / discrete Fourier Transform (DFT)- spread (s)-OFDM symbol followed by last symbol of PDSCH transmission. Note that transmission duration of PDSCH may be configured by higher layers, dynamically indicated by MAC-CE, or indicated by DCI

carried by a first PDCCH. Further, in case of early termination of PDSCH transmission, UE may start to monitor PDCCH after the last symbol of PDSCH transmission after early termination.

The techniques described herein provide additional opportunity of the PDCCH transmission with flexible / dynamic position comparing to PDCCH monitoring occasions configured by higher layers. As the result PDSCHs can be scheduled in contiguous manner (avoiding unused symbols) as illustrated in Figure 13.

In another example, the additional PDCCH monitoring occasions may start in $X > 0$ symbols after last symbol of PDSCH as shown in Figure 14. In another option, additional flexible PDCCH monitoring occasion may be indicated by a first PDCCH scheduling PDSCH transmission.

It should be noted that due to more flexible PDCCH position the additional collisions of the physical channels may occur. For example:

- Collision between PDSCH scheduled by additional PDCCH and PDCCH monitoring occasion configured by RRC; and/or
- Collision between additional PDCCH and PDCCH monitoring occasion configured by RRC.

For the first collision example, e.g., PDSCH scheduled by additional PDCCH may collide with PDCCH monitoring occasion configured by RRC, the priorities for processing of the physical channels should be defined. For example, UE may assume that PDSCH transmission is prioritized in the corresponding OFDM symbols and potential PDCCH is dropped. In another example, UE may assume that PDCCH monitoring is prioritized and PDSCH transmission in the corresponding symbols is dropped or rate-matching around the PDCCH transmission in the corresponding PDCCH monitoring occasion.

In another example, if the PDSCH transmission uses a different transmission control indicator (TCI) state (beam) from PDCCH configured by RRC and the UE has the capability to receive two or more TCI states (beams), UE can detect the PDCCH configured by RRC and do PDSCH reception simultaneously.

For the second collision example, e.g., collision of additional PDCCH and PDCCH monitoring occasion configured by RRC, the priorities for processing of the physical channels should be defined. In one example more priority is given to monitoring of the additional PDCCH comparing to PDCCH configured by RRC. In another example, more priority is given

to monitoring of the PDCCH configured by RRC comparing to additional PDCCH. In another example, the priority is given by the associated ID of the CORESET.

In another example, if the additional PDCCH uses a different TCI state (beam) from PDCCH configured by RRC and the UE has the capability to receive two or more TCI states (beams), UE can detect both the additional PDCCH and the PDCCH configured by RRC simultaneously.

SYSTEMS AND IMPLEMENTATIONS

Figures 15-17 illustrate various systems, devices, and components that may implement aspects of disclosed embodiments.

Figure 15 illustrates a network 1500 in accordance with various embodiments. The network 1500 may operate in a manner consistent with 3GPP technical specifications for LTE or 5G/NR systems. However, the example embodiments are not limited in this regard and the described embodiments may apply to other networks that benefit from the principles described herein, such as future 3GPP systems, or the like.

The network 1500 may include a UE 1502, which may include any mobile or non-mobile computing device designed to communicate with a RAN 1504 via an over-the-air connection. The UE 1502 may be, but is not limited to, a smartphone, tablet computer, wearable computer device, desktop computer, laptop computer, in-vehicle infotainment, in-car entertainment device, instrument cluster, head-up display device, onboard diagnostic device, dashtop mobile equipment, mobile data terminal, electronic engine management system, electronic/engine control unit, electronic/engine control module, embedded system, sensor, microcontroller, control module, engine management system, networked appliance, machine-type communication device, M2M or D2D device, IoT device, etc.

In some embodiments, the network 1500 may include a plurality of UEs coupled directly with one another via a sidelink interface. The UEs may be M2M/D2D devices that communicate using physical sidelink channels such as, but not limited to, PSBCH, PSDCH, PSSCH, PSCCH, PSFCH, etc.

In some embodiments, the UE 1502 may additionally communicate with an AP 1506 via an over-the-air connection. The AP 1506 may manage a WLAN connection, which may serve to offload some/all network traffic from the RAN 1504. The connection between the UE 1502 and the AP 1506 may be consistent with any IEEE 802.11 protocol, wherein the AP 1506 could be a wireless fidelity (Wi-Fi®) router. In some embodiments, the UE 1502, RAN 1504, and AP 1506 may utilize cellular-WLAN aggregation (for example, LWA/LWIP). Cellular-

WLAN aggregation may involve the UE 1502 being configured by the RAN 1504 to utilize both cellular radio resources and WLAN resources.

The RAN 1504 may include one or more access nodes, for example, AN 1508. AN 1508 may terminate air-interface protocols for the UE 1502 by providing access stratum protocols including RRC, PDCP, RLC, MAC, and L1 protocols. In this manner, the AN 1508 may enable data/voice connectivity between CN 1520 and the UE 1502. In some embodiments, the AN 1508 may be implemented in a discrete device or as one or more software entities running on server computers as part of, for example, a virtual network, which may be referred to as a CRAN or virtual baseband unit pool. The AN 1508 be referred to as a BS, gNB, RAN node, eNB, ng-eNB, NodeB, RSU, TRxP, TRP, etc. The AN 1508 may be a macrocell base station or a low power base station for providing femtocells, picocells or other like cells having smaller coverage areas, smaller user capacity, or higher bandwidth compared to macrocells.

In embodiments in which the RAN 1504 includes a plurality of ANs, they may be coupled with one another via an X2 interface (if the RAN 1504 is an LTE RAN) or an Xn interface (if the RAN 1504 is a 5G RAN). The X2/Xn interfaces, which may be separated into control/user plane interfaces in some embodiments, may allow the ANs to communicate information related to handovers, data/context transfers, mobility, load management, interference coordination, etc.

The ANs of the RAN 1504 may each manage one or more cells, cell groups, component carriers, etc. to provide the UE 1502 with an air interface for network access. The UE 1502 may be simultaneously connected with a plurality of cells provided by the same or different ANs of the RAN 1504. For example, the UE 1502 and RAN 1504 may use carrier aggregation to allow the UE 1502 to connect with a plurality of component carriers, each corresponding to a Pcell or Scell. In dual connectivity scenarios, a first AN may be a master node that provides an MCG and a second AN may be secondary node that provides an SCG. The first/second ANs may be any combination of eNB, gNB, ng-eNB, etc.

The RAN 1504 may provide the air interface over a licensed spectrum or an unlicensed spectrum. To operate in the unlicensed spectrum, the nodes may use LAA, eLAA, and/or feLAA mechanisms based on CA technology with PCells/Scells. Prior to accessing the unlicensed spectrum, the nodes may perform medium/carrier-sensing operations based on, for example, a listen-before-talk (LBT) protocol.

In V2X scenarios the UE 1502 or AN 1508 may be or act as a RSU, which may refer to any transportation infrastructure entity used for V2X communications. An RSU may be implemented in or by a suitable AN or a stationary (or relatively stationary) UE. An RSU

implemented in or by: a UE may be referred to as a "UE-type RSU"; an eNB may be referred to as an "eNB-type RSU"; a gNB may be referred to as a "gNB-type RSU"; and the like. In one example, an RSU is a computing device coupled with radio frequency circuitry located on a roadside that provides connectivity support to passing vehicle UEs. The RSU may also include internal data storage circuitry to store intersection map geometry, traffic statistics, media, as well as applications/software to sense and control ongoing vehicular and pedestrian traffic. The RSU may provide very low latency communications required for high speed events, such as crash avoidance, traffic warnings, and the like. Additionally or alternatively, the RSU may provide other cellular/WLAN communications services. The components of the RSU may be packaged in a weatherproof enclosure suitable for outdoor installation, and may include a network interface controller to provide a wired connection (e.g., Ethernet) to a traffic signal controller or a backhaul network.

In some embodiments, the RAN 1504 may be an LTE RAN 1510 with eNBs, for example, eNB 1512. The LTE RAN 1510 may provide an LTE air interface with the following characteristics: SCS of 15 kHz; CP-OFDM waveform for DL and SC-FDMA waveform for UL; turbo codes for data and TBCC for control; etc. The LTE air interface may rely on CSI-RS for CSI acquisition and beam management; PDSCH/PDCCH DMRS for PDSCH/PDCCH demodulation; and CRS for cell search and initial acquisition, channel quality measurements, and channel estimation for coherent demodulation/detection at the UE. The LTE air interface may operating on sub-6 GHz bands.

In some embodiments, the RAN 1504 may be an NG-RAN 1514 with gNBs, for example, gNB 1516, or ng-eNBs, for example, ng-eNB 1518. The gNB 1516 may connect with 5G-enabled UEs using a 5G NR interface. The gNB 1516 may connect with a 5G core through an NG interface, which may include an N2 interface or an N3 interface. The ng-eNB 1518 may also connect with the 5G core through an NG interface, but may connect with a UE via an LTE air interface. The gNB 1516 and the ng-eNB 1518 may connect with each other over an Xn interface.

In some embodiments, the NG interface may be split into two parts, an NG user plane (NG-U) interface, which carries traffic data between the nodes of the NG-RAN 1514 and a UPF 1548 (e.g., N3 interface), and an NG control plane (NG-C) interface, which is a signaling interface between the nodes of the NG-RAN1514 and an AMF 1544 (e.g., N2 interface).

The NG-RAN 1514 may provide a 5G-NR air interface with the following characteristics: variable SCS; CP-OFDM for DL, CP-OFDM and DFT-s-OFDM for UL; polar, repetition, simplex, and Reed-Muller codes for control and LDPC for data. The 5G-NR air

interface may rely on CSI-RS, PDSCH/PDCCH DMRS similar to the LTE air interface. The 5G-NR air interface may not use a CRS, but may use PBCH DMRS for PBCH demodulation; PTRS for phase tracking for PDSCH; and tracking reference signal for time tracking. The 5G-NR air interface may operating on FR1 bands that include sub-6 GHz bands or FR2 bands that include bands from 24.25 GHz to 52.6 GHz. The 5G-NR air interface may include an SSB that is an area of a downlink resource grid that includes PSS/SSS/PBCH.

In some embodiments, the 5G-NR air interface may utilize BWPs for various purposes. For example, BWP can be used for dynamic adaptation of the SCS. For example, the UE 1502 can be configured with multiple BWPs where each BWP configuration has a different SCS. When a BWP change is indicated to the UE 1502, the SCS of the transmission is changed as well. Another use case example of BWP is related to power saving. In particular, multiple BWPs can be configured for the UE 1502 with different amount of frequency resources (for example, PRBs) to support data transmission under different traffic loading scenarios. A BWP containing a smaller number of PRBs can be used for data transmission with small traffic load while allowing power saving at the UE 1502 and in some cases at the gNB 1516. A BWP containing a larger number of PRBs can be used for scenarios with higher traffic load.

The RAN 1504 is communicatively coupled to CN 1520 that includes network elements to provide various functions to support data and telecommunications services to customers/subscribers (for example, users of UE 1502). The components of the CN 1520 may be implemented in one physical node or separate physical nodes. In some embodiments, NFV may be utilized to virtualize any or all of the functions provided by the network elements of the CN 1520 onto physical compute/storage resources in servers, switches, etc. A logical instantiation of the CN 1520 may be referred to as a network slice, and a logical instantiation of a portion of the CN 1520 may be referred to as a network sub-slice.

In some embodiments, the CN 1520 may be an LTE CN 1522, which may also be referred to as an EPC. The LTE CN 1522 may include MME 1524, SGW 1526, SGSN 1528, HSS 1530, PGW 1532, and PCRF 1534 coupled with one another over interfaces (or "reference points") as shown. Functions of the elements of the LTE CN 1522 may be briefly introduced as follows.

The MME 1524 may implement mobility management functions to track a current location of the UE 1502 to facilitate paging, bearer activation/deactivation, handovers, gateway selection, authentication, etc.

The SGW 1526 may terminate an S1 interface toward the RAN and route data packets between the RAN and the LTE CN 1522. The SGW 1526 may be a local mobility anchor point

for inter-RAN node handovers and also may provide an anchor for inter-3GPP mobility. Other responsibilities may include lawful intercept, charging, and some policy enforcement.

The SGSN 1528 may track a location of the UE 1502 and perform security functions and access control. In addition, the SGSN 1528 may perform inter-EPC node signaling for mobility between different RAT networks; PDN and S-GW selection as specified by MME 1524; MME selection for handovers; etc. The S3 reference point between the MME 1524 and the SGSN 1528 may enable user and bearer information exchange for inter-3GPP access network mobility in idle/active states.

The HSS 1530 may include a database for network users, including subscription-related information to support the network entities' handling of communication sessions. The HSS 1530 can provide support for routing/roaming, authentication, authorization, naming/addressing resolution, location dependencies, etc. An S6a reference point between the HSS 1530 and the MME 1524 may enable transfer of subscription and authentication data for authenticating/authorizing user access to the LTE CN 1520.

The PGW 1532 may terminate an SGi interface toward a data network (DN) 1536 that may include an application/content server 1538. The PGW 1532 may route data packets between the LTE CN 1522 and the data network 1536. The PGW 1532 may be coupled with the SGW 1526 by an S5 reference point to facilitate user plane tunneling and tunnel management. The PGW 1532 may further include a node for policy enforcement and charging data collection (for example, PCEF). Additionally, the SGi reference point between the PGW 1532 and the data network 15 36 may be an operator external public, a private PDN, or an intra-operator packet data network, for example, for provision of IMS services. The PGW 1532 may be coupled with a PCRF 1534 via a Gx reference point.

The PCRF 1534 is the policy and charging control element of the LTE CN 1522. The PCRF 1534 may be communicatively coupled to the app/content server 1538 to determine appropriate QoS and charging parameters for service flows. The PCRF 1532 may provision associated rules into a PCEF (via Gx reference point) with appropriate TFT and QCI.

In some embodiments, the CN 1520 may be a 5GC 1540. The 5GC 1540 may include an AUSF 1542, AMF 1544, SMF 1546, UPF 1548, NSSF 1550, NEF 1552, NRF 1554, PCF 1556, UDM 1558, and AF 1560 coupled with one another over interfaces (or "reference points") as shown. Functions of the elements of the 5GC 1540 may be briefly introduced as follows.

The AUSF 1542 may store data for authentication of UE 1502 and handle authentication-related functionality. The AUSF 1542 may facilitate a common authentication

framework for various access types. In addition to communicating with other elements of the 5GC 1540 over reference points as shown, the AUSF 1542 may exhibit an Nausf service-based interface.

The AMF 1544 may allow other functions of the 5GC 1540 to communicate with the UE 1502 and the RAN 1504 and to subscribe to notifications about mobility events with respect to the UE 1502. The AMF 1544 may be responsible for registration management (for example, for registering UE 1502), connection management, reachability management, mobility management, lawful interception of AMF-related events, and access authentication and authorization. The AMF 1544 may provide transport for SM messages between the UE 1502 and the SMF 1546, and act as a transparent proxy for routing SM messages. AMF 1544 may also provide transport for SMS messages between UE 1502 and an SMSF. AMF 1544 may interact with the AUSF 1542 and the UE 1502 to perform various security anchor and context management functions. Furthermore, AMF 1544 may be a termination point of a RAN CP interface, which may include or be an N2 reference point between the RAN 1504 and the AMF 1544; and the AMF 1544 may be a termination point of NAS (N1) signaling, and perform NAS ciphering and integrity protection. AMF 1544 may also support NAS signaling with the UE 1502 over an N3 IWF interface.

The SMF 1546 may be responsible for SM (for example, session establishment, tunnel management between UPF 1548 and AN 1508); UE IP address allocation and management (including optional authorization); selection and control of UP function; configuring traffic steering at UPF 1548 to route traffic to proper destination; termination of interfaces toward policy control functions; controlling part of policy enforcement, charging, and QoS; lawful intercept (for SM events and interface to LI system); termination of SM parts of NAS messages; downlink data notification; initiating AN specific SM information, sent via AMF 1544 over N2 to AN 1508; and determining SSC mode of a session. SM may refer to management of a PDU session, and a PDU session or "session" may refer to a PDU connectivity service that provides or enables the exchange of PDUs between the UE 1502 and the data network 1536.

The UPF 1548 may act as an anchor point for intra-RAT and inter-RAT mobility, an external PDU session point of interconnect to data network 1536, and a branching point to support multi-homed PDU session. The UPF 1548 may also perform packet routing and forwarding, perform packet inspection, enforce the user plane part of policy rules, lawfully intercept packets (UP collection), perform traffic usage reporting, perform QoS handling for a user plane (e.g., packet filtering, gating, UL/DL rate enforcement), perform uplink traffic verification (e.g., SDF-to-QoS flow mapping), transport level packet marking in the uplink and

downlink, and perform downlink packet buffering and downlink data notification triggering. UPF 1548 may include an uplink classifier to support routing traffic flows to a data network.

The NSSF 1550 may select a set of network slice instances serving the UE 1502. The NSSF 1550 may also determine allowed NSSAI and the mapping to the subscribed S-NSSAIs, if needed. The NSSF 1550 may also determine the AMF set to be used to serve the UE 1502, or a list of candidate AMFs based on a suitable configuration and possibly by querying the NRF 1554. The selection of a set of network slice instances for the UE 1502 may be triggered by the AMF 1544 with which the UE 1502 is registered by interacting with the NSSF 1550, which may lead to a change of AMF. The NSSF 1550 may interact with the AMF 1544 via an N22 reference point; and may communicate with another NSSF in a visited network via an N31 reference point (not shown). Additionally, the NSSF 1550 may exhibit an Nnssf service-based interface.

The NEF 1552 may securely expose services and capabilities provided by 3GPP network functions for third party, internal exposure/re-exposure, AFs (e.g., AF 1560), edge computing or fog computing systems, etc. In such embodiments, the NEF 1552 may authenticate, authorize, or throttle the AFs. NEF 1552 may also translate information exchanged with the AF 1560 and information exchanged with internal network functions. For example, the NEF 1552 may translate between an AF-Service-Identifier and an internal 5GC information. NEF 1552 may also receive information from other NFs based on exposed capabilities of other NFs. This information may be stored at the NEF 1552 as structured data, or at a data storage NF using standardized interfaces. The stored information can then be re-exposed by the NEF 1552 to other NFs and AFs, or used for other purposes such as analytics. Additionally, the NEF 1552 may exhibit an Nnef service-based interface.

The NRF 1554 may support service discovery functions, receive NF discovery requests from NF instances, and provide the information of the discovered NF instances to the NF instances. NRF 1554 also maintains information of available NF instances and their supported services. As used herein, the terms “instantiate,” “instantiation,” and the like may refer to the creation of an instance, and an “instance” may refer to a concrete occurrence of an object, which may occur, for example, during execution of program code. Additionally, the NRF 1554 may exhibit the Nnrf service-based interface.

The PCF 1556 may provide policy rules to control plane functions to enforce them, and may also support unified policy framework to govern network behavior. The PCF 1556 may also implement a front end to access subscription information relevant for policy decisions in a UDR of the UDM 1558. In addition to communicating with functions over reference points

as shown, the PCF 1556 exhibit an Npcf service-based interface.

The UDM 1558 may handle subscription-related information to support the network entities' handling of communication sessions, and may store subscription data of UE 1502. For example, subscription data may be communicated via an N8 reference point between the UDM 1558 and the AMF 1544. The UDM 1558 may include two parts, an application front end and a UDR. The UDR may store subscription data and policy data for the UDM 1558 and the PCF 1556, and/or structured data for exposure and application data (including PFDs for application detection, application request information for multiple UEs 1502) for the NEF 1552. The Nudr service-based interface may be exhibited by the UDR 221 to allow the UDM 1558, PCF 1556, and NEF 1552 to access a particular set of the stored data, as well as to read, update (e.g., add, modify), delete, and subscribe to notification of relevant data changes in the UDR. The UDM may include a UDM-FE, which is in charge of processing credentials, location management, subscription management and so on. Several different front ends may serve the same user in different transactions. The UDM-FE accesses subscription information stored in the UDR and performs authentication credential processing, user identification handling, access authorization, registration/mobility management, and subscription management. In addition to communicating with other NFs over reference points as shown, the UDM 1558 may exhibit the Nudm service-based interface.

The AF 1560 may provide application influence on traffic routing, provide access to NEF, and interact with the policy framework for policy control.

In some embodiments, the 5GC 1540 may enable edge computing by selecting operator/3rd party services to be geographically close to a point that the UE 1502 is attached to the network. This may reduce latency and load on the network. To provide edge-computing implementations, the 5GC 1540 may select a UPF 1548 close to the UE 1502 and execute traffic steering from the UPF 1548 to data network 1536 via the N6 interface. This may be based on the UE subscription data, UE location, and information provided by the AF 1560. In this way, the AF 1560 may influence UPF (re)selection and traffic routing. Based on operator deployment, when AF 1560 is considered to be a trusted entity, the network operator may permit AF 1560 to interact directly with relevant NFs. Additionally, the AF 1560 may exhibit an Naf service-based interface.

The data network 1536 may represent various network operator services, Internet access, or third party services that may be provided by one or more servers including, for example, application/content server 1538.

Figure 16 schematically illustrates a wireless network 1600 in accordance with various

embodiments. The wireless network 1600 may include a UE 1602 in wireless communication with an AN 1604. The UE 1602 and AN 1604 may be similar to, and substantially interchangeable with, like-named components described elsewhere herein.

The UE 1602 may be communicatively coupled with the AN 1604 via connection 1606. The connection 1606 is illustrated as an air interface to enable communicative coupling, and can be consistent with cellular communications protocols such as an LTE protocol or a 5G NR protocol operating at mmWave or sub-6GHz frequencies.

The UE 1602 may include a host platform 1608 coupled with a modem platform 1610. The host platform 1608 may include application processing circuitry 1612, which may be coupled with protocol processing circuitry 1614 of the modem platform 1610. The application processing circuitry 1612 may run various applications for the UE 1602 that source/sink application data. The application processing circuitry 1612 may further implement one or more layer operations to transmit/receive application data to/from a data network. These layer operations may include transport (for example UDP) and Internet (for example, IP) operations

The protocol processing circuitry 1614 may implement one or more of layer operations to facilitate transmission or reception of data over the connection 1606. The layer operations implemented by the protocol processing circuitry 1614 may include, for example, MAC, RLC, PDCP, RRC and NAS operations.

The modem platform 1610 may further include digital baseband circuitry 1616 that may implement one or more layer operations that are "below" layer operations performed by the protocol processing circuitry 1614 in a network protocol stack. These operations may include, for example, PHY operations including one or more of HARQ-ACK functions, scrambling/descrambling, encoding/decoding, layer mapping/de-mapping, modulation symbol mapping, received symbol/bit metric determination, multi-antenna port precoding/decoding, which may include one or more of space-time, space-frequency or spatial coding, reference signal generation/detection, preamble sequence generation and/or decoding, synchronization sequence generation/detection, control channel signal blind decoding, and other related functions.

The modem platform 1610 may further include transmit circuitry 1618, receive circuitry 1620, RF circuitry 1622, and RF front end (RFFE) 1624, which may include or connect to one or more antenna panels 1626. Briefly, the transmit circuitry 1618 may include a digital-to-analog converter, mixer, intermediate frequency (IF) components, etc.; the receive circuitry 1620 may include an analog-to-digital converter, mixer, IF components, etc.;

the RF circuitry 1622 may include a low-noise amplifier, a power amplifier, power tracking components, etc.; RFFE 1624 may include filters (for example, surface/bulk acoustic wave filters), switches, antenna tuners, beamforming components (for example, phase-array antenna components), etc. The selection and arrangement of the components of the transmit circuitry 1618, receive circuitry 1620, RF circuitry 1622, RFFE 1624, and antenna panels 1626 (referred generically as "transmit/receive components") may be specific to details of a specific implementation such as, for example, whether communication is TDM or FDM, in mmWave or sub-6 gHz frequencies, etc. In some embodiments, the transmit/receive components may be arranged in multiple parallel transmit/receive chains, may be disposed in the same or different chips/modules, etc.

In some embodiments, the protocol processing circuitry 1614 may include one or more instances of control circuitry (not shown) to provide control functions for the transmit/receive components.

A UE reception may be established by and via the antenna panels 1626, RFFE 1624, RF circuitry 1622, receive circuitry 1620, digital baseband circuitry 1616, and protocol processing circuitry 1614. In some embodiments, the antenna panels 1626 may receive a transmission from the AN 1604 by receive-beamforming signals received by a plurality of antennas/antenna elements of the one or more antenna panels 1626.

A UE transmission may be established by and via the protocol processing circuitry 1614, digital baseband circuitry 1616, transmit circuitry 1618, RF circuitry 1622, RFFE 1624, and antenna panels 1626. In some embodiments, the transmit components of the UE 1604 may apply a spatial filter to the data to be transmitted to form a transmit beam emitted by the antenna elements of the antenna panels 1626.

Similar to the UE 1602, the AN 1604 may include a host platform 1628 coupled with a modem platform 1630. The host platform 1628 may include application processing circuitry 1632 coupled with protocol processing circuitry 1634 of the modem platform 1630. The modem platform may further include digital baseband circuitry 1636, transmit circuitry 1638, receive circuitry 1640, RF circuitry 1642, RFFE circuitry 1644, and antenna panels 1646. The components of the AN 1604 may be similar to and substantially interchangeable with like-named components of the UE 1602. In addition to performing data transmission/reception as described above, the components of the AN 1608 may perform various logical functions that include, for example, RNC functions such as radio bearer management, uplink and downlink dynamic radio resource management, and data packet scheduling.

Figure 17 is a block diagram illustrating components, according to some example embodiments, able to read instructions from a machine-readable or computer-readable medium (e.g., a non-transitory machine-readable storage medium) and perform any one or more of the methodologies discussed herein. Specifically, Figure 17 shows a diagrammatic representation of hardware resources 1700 including one or more processors (or processor cores) 1710, one or more memory/storage devices 1720, and one or more communication resources 1730, each of which may be communicatively coupled via a bus 1740 or other interface circuitry. For embodiments where node virtualization (e.g., NFV) is utilized, a hypervisor 1702 may be executed to provide an execution environment for one or more network slices/sub-slices to utilize the hardware resources 1700.

The processors 1710 may include, for example, a processor 1712 and a processor 1714. The processors 1710 may be, for example, a central processing unit (CPU), a reduced instruction set computing (RISC) processor, a complex instruction set computing (CISC) processor, a graphics processing unit (GPU), a DSP such as a baseband processor, an ASIC, an FPGA, a radio-frequency integrated circuit (RFIC), another processor (including those discussed herein), or any suitable combination thereof.

The memory/storage devices 1720 may include main memory, disk storage, or any suitable combination thereof. The memory/storage devices 1720 may include, but are not limited to, any type of volatile, non-volatile, or semi-volatile memory such as dynamic random access memory (DRAM), static random access memory (SRAM), erasable programmable read-only memory (EPROM), electrically erasable programmable read-only memory (EEPROM), Flash memory, solid-state storage, etc.

The communication resources 1730 may include interconnection or network interface controllers, components, or other suitable devices to communicate with one or more peripheral devices 1704 or one or more databases 1706 or other network elements via a network 1708. For example, the communication resources 1730 may include wired communication components (e.g., for coupling via USB, Ethernet, etc.), cellular communication components, NFC components, Bluetooth® (or Bluetooth® Low Energy) components, Wi-Fi® components, and other communication components.

Instructions 1750 may comprise software, a program, an application, an applet, an app, or other executable code for causing at least any of the processors 1710 to perform any one or more of the methodologies discussed herein. The instructions 1750 may reside, completely or partially, within at least one of the processors 1710 (e.g., within the processor's cache memory), the memory/storage devices 1720, or any suitable combination thereof. Furthermore, any

portion of the instructions 1750 may be transferred to the hardware resources 1700 from any combination of the peripheral devices 1704 or the databases 1706. Accordingly, the memory of processors 1710, the memory/storage devices 1720, the peripheral devices 1704, and the databases 1706 are examples of computer-readable and machine-readable media.

EXAMPLE PROCEDURES

In some embodiments, the electronic device(s), network(s), system(s), chip(s) or component(s), or portions or implementations thereof, of Figures 15-17, or some other figure herein, may be configured to perform one or more processes, techniques, or methods as described herein, or portions thereof. One such process 1800 is depicted in Figure 18. For example, the process 1800 may include, at 1802, receiving a downlink control information (DCI) to indicate a resource allocation for transmission of a transport block, wherein the resource allocation includes one or more code block groups (CBGs) mapped to one or more symbol alignment units (SAUs) of one or more symbols.

At 1804, the process 1800 may further include causing transmission or reception of the transport block based on the DCI. In some embodiments, the process 1800 may be performed by a UE or a portion thereof.

Figure 19 illustrates another process 1900 in accordance with various embodiments. The process may include, at 1902, receiving a downlink control information (DCI) to indicate respective resource allocations for two or more transport blocks, wherein the resource allocations include one or more symbol alignment units (SAUs), wherein the SAUs include all time-frequency resources of one or more symbols.

At 1904, the process 1900 may further include causing transmission or reception of the transport blocks based on the DCI. In some embodiments, the process 1900 may be performed by a UE or a portion thereof.

Figure 20 illustrates another process 2000 in accordance with various embodiments. The process 2000 may include, at 2002, encoding, for transmission to a UE, a downlink control information (DCI) to indicate a resource allocation for transmission of a transport block, wherein the resource allocation includes one or more code block groups (CBGs) mapped to one or more symbol alignment units (SAUs) of one or more symbols.

At 2004, the process 2000 may further include causing transmission of the transport block to the UE or reception of the transport block from the UE based on the DCI. In some embodiments, the process 2000 may be performed by a gNB or a portion thereof.

Figure 21 illustrates another process 2100 in accordance with various embodiments. The process 2100 may include, at 2102, encoding, for transmission to a UE, a downlink control information (DCI) to indicate respective resource allocations for two or more transport blocks, wherein the resource allocations include one or more symbol alignment units (SAUs), wherein the SAUs include all time-frequency resources of one or more symbols.

At 2104, the process 2100 may further include causing transmission of the transport blocks to the UE or reception of the transport blocks from the UE based on the DCI. In some embodiments, the process 2100 may be performed by a gNB or a portion thereof.

Figure 22 illustrates another process 2200 in accordance with various embodiments. In some embodiments, the process 2200 may be performed by a UE or a portion thereof. For example, the process 2200 may include, at 2202, determining a last symbol of a PDSCH (e.g., a PDSCH received by the UE).

At 2204, the process 2200 may further include determining a PDCCH monitoring occasion for a PDCCH based on the last symbol of the PDSCH. For example, the PDCCH monitoring occasion may be determined as beginning a number of symbols after the last symbol (e.g., the next symbol after the last symbol or another number of symbols after the last symbol).

At 2206, the process 2200 may further include monitoring for a PDCCH in the determined PDCCH monitoring occasion. In some embodiments, the process may further include receiving the PDCCH in the PDCCH monitoring occasion. The PDCCH may schedule another communication for the UE, such as a downlink communication (e.g., another PDSCH) and/or an uplink communication (e.g., a PUSCH and/or PUCCH).

Figure 23 illustrates another process 2300 in accordance with various embodiments. In some embodiments, the process 2300 may be performed by a gNB or a portion thereof.

At 2302, the process 2300 may include encoding a PDSCH for transmission (e.g., to a UE).

At 2304, the process may further include determining a PDCCH monitoring occasion for a PDCCH based on a last symbol of the PDSCH. For example, the PDCCH monitoring occasion may be determined as beginning a number of symbols after the last symbol (e.g., the next symbol after the last symbol or another number of symbols after the last symbol).

At 2306, the process may further include encoding the PDCCH for transmission in the determined PDCCH monitoring occasion (e.g., to the UE or another UE). The PDCCH may

schedule another communication for a UE, such as a downlink communication (e.g., another PDSCH) and/or an uplink communication (e.g., a PUSCH and/or PUCCH).

For one or more embodiments, at least one of the components set forth in one or more of the preceding figures may be configured to perform one or more operations, techniques, processes, and/or methods as set forth in the example section below. For example, the baseband circuitry as described above in connection with one or more of the preceding figures may be configured to operate in accordance with one or more of the examples set forth below. For another example, circuitry associated with a UE, base station, network element, etc. as described above in connection with one or more of the preceding figures may be configured to operate in accordance with one or more of the examples set forth below in the example section.

EXAMPLES

Example 1 may include a method of wireless communication for scheduling data transmissions for above 52.6GHz carrier frequency.

Example 2 may include the method of example 1 or some other example herein, wherein a CBG is mapped to all time/frequency resource of certain consecutive symbols.

Example 3 may include the method of example 1 or some other example herein, wherein a CBG is mapped to a symbol alignment unit (SAU); or, a CBG is mapped to one or multiple SAUs; or, a SAU consist of one or multiple CBGs.

Example 4 may include the method of example 1 or some other example herein, wherein the start and length indicator (SLIV) in the DCI indicates the time resource of a CBG.

Example 5 may include the method of example 1 or some other example herein, wherein SLIV in the DCI indicates the time resource of a SAU.

Example 6 may include the method of example 1 or some other example herein, wherein early termination of a PDSCH or PUSCH transmission is supported with the granularity of one TB, one CBG or one SAU.

Example 7 may include the method of example 1 or some other example herein, wherein a DCI schedules a PDSCH or a PUSCH which carries only one TB with multiple CBGs.

Example 8 may include the method of example 7 or some other example herein, wherein SLIV in the DCI indicates the time resource of a CBG.

Example 9 may include the method of example 1 or some other example herein, wherein a DCI schedules a PDSCH or a PUSCH which carries only one TB with one or multiple SAUs.

Example 10 may include the method of example 9 or some other example herein, wherein SLIV in the DCI indicates the time resource of a SAU.

Example 11 may include the method of example 10 or some other example herein, wherein the evenly distributed SAUs are mapped to the same CBG, or the consecutive SAUs are mapped to the same CBG.

Example 12 may include the method of example 1 or some other example herein, wherein a DCI schedules a transmission which carries multiple TBs without CBGs.

Example 13 may include the method of example 12 or some other example herein, wherein SLIV in the DCI indicates the time resource of a SAU.

Example 14 may include the method of example 13 or some other example herein, wherein the consecutive SAUs are mapped to the same TB, or, the evenly distributed SAUs are mapped to the same TB.

Example 15 may include the method of example 1 or some other example herein, wherein a DCI schedules a transmission which carries multiple TBs with CBGs.

Example 16 may include the method of example 15 or some other example herein, wherein SLIV in the DCI indicates the time resource of a CBG.

Example 17 may include the method of example 16 or some other example herein, wherein the evenly distributed CBGs are mapped to the same TB, or, the consecutive CBGs are mapped to the same TB.

Example 18 may include the method of example 15 or some other example herein, wherein SLIV in the DCI indicates the time resource of a SAU.

Example 19 may include the method of example 18 or some other example herein, wherein the consecutive SAUs are mapped to the same CBG, or, the evenly distributed SAUs are mapped to the same CBG.

Example 20 may include a method comprising:

receiving a downlink control information (DCI) to indicate a resource allocation for transmission of a transport block, wherein the resource allocation includes one or more code block groups (CBGs) mapped to one or more symbol alignment units (SAUs) of one or more symbols; and

transmitting or receiving the transport block based on the DCI.

Example 21 may include the method of example 20 or some other example herein, wherein individual CBGs are mapped to all time-frequency resources of the one or more symbols of the respective one or more SAUs.

Example 22 may include the method of example 20-21 or some other example herein, wherein the DCI includes a start length indicator value (SLIV) to indicate a time resource of a first CBG of the one or more CBGs.

Example 23 may include the method of example 20-21 or some other example herein, wherein the DCI includes a SLIV to indicate a time resource of a first SAU of the one or more SAUs.

Example 24 may include the method of example 20-23 or some other example herein, further comprising determining early termination of the transmission, wherein the early termination is determined with a granularity of one transport block, one CBG, or one SAU.

Example 25 may include the method of example 20-24 or some other example herein, wherein the DCI schedules transmission of the single transport block.

Example 26 may include the method of example 25 or some other example herein, wherein the transport block includes multiple CBGs.

Example 27 may include the method of example 25 or some other example herein, wherein the transport block includes multiple SAUs.

Example 28 may include the method of example 20-24 or some other example herein, wherein the DCI schedules transmission of multiple transport blocks.

Example 29 may include the method of example 28 or some other example herein, wherein the resource allocations for individual transport blocks correspond to consecutive time-frequency resources.

Example 30 may include the method of example 28 or some other example herein, wherein the CBGs and/or SAUs of the multiple transport blocks are interlaced with one another in the time domain.

Example 31 may include the method of example 20-30 or some other example herein, wherein respective CBGs include multiple SAUs.

Example 32 may include the method of example 31 or some other example herein, wherein the multiple SAUs are consecutive in the time domain.

Example 33 may include the method of example 31 or some other example herein, wherein the multiple SAUs are interlaced in the time domain with other SAUs of the resource allocation.

Example 34 may include the method of example 20-33, further comprising generating or receiving HARQ feedback for individual CBGs of the resource allocation.

Example 35 may include the method of example 20-34 or some other example herein, wherein the transport block is a PUSCH.

Example 36 may include the method of example 20-34 or some other example herein, wherein the transport block is a PDSCH.

Example 37 may include the method of example 20-36 or some other example herein, wherein the method is performed by a UE or a portion thereof.

Example 38 may include a method comprising:

receiving a downlink control information (DCI) to indicate respective resource allocations for two or more transport blocks, wherein the resource allocations include one or more symbol alignment units (SAUs), wherein the SAUs include all time-frequency resources of one or more symbols; and

transmitting or receiving the transport blocks based on the DCI.

Example 39 may include the method of example 38 or some other example herein, wherein the individual resource allocations include multiple SAUs.

Example 40 may include the method of example 38-39 or some other example herein, wherein the multiple SAUs are consecutive in the time domain.

Example 41 may include the method of example 38-39 or some other example herein, wherein the multiple SAUs are interlaced in the time domain with the SAUs of one or more other resource allocations.

Example 42 may include the method of example 38-41, further comprising generating or receiving HARQ feedback for individual SAUs of the resource allocations.

Example 43 may include the method of example 38-42 or some other example herein, wherein the transport blocks are transmitted on a PUSCH.

Example 44 may include the method of example 38-42 or some other example herein, wherein the transport blocks are transmitted on a PDSCH.

Example 45 may include the method of example 38-44 or some other example herein, wherein the method is performed by a UE or a portion thereof.

Example 46 may include a method comprising:

encoding, for transmission to a UE, a downlink control information (DCI) to indicate a resource allocation for transmission of a transport block, wherein the resource allocation includes one or more code block groups (CBGs) mapped to one or more symbol alignment units (SAUs) of one or more symbols; and

causing transmission of the transport block to the UE or reception of the transport block from the UE based on the DCI.

Example 47 may include the method of example 46 or some other example herein, wherein individual CBGs are mapped to all time-frequency resources of the one or more symbols of the respective one or more SAUs.

Example 48 may include the method of example 46-47 or some other example herein, wherein the DCI includes a start length indicator value (SLIV) to indicate a time resource of a first CBG of the one or more CBGs.

Example 49 may include the method of example 46-47 or some other example herein, wherein the DCI includes a SLIV to indicate a time resource of a first SAU of the one or more SAUs.

Example 50 may include the method of example 46-49 or some other example herein, further comprising determining early termination of the transmission, wherein the early termination is determined with a granularity of one transport block, one CBG, or one SAU.

Example 51 may include the method of example 46-50 or some other example herein, wherein the DCI schedules transmission of the single transport block.

Example 52 may include the method of example 51 or some other example herein, wherein the transport block includes multiple CBGs.

Example 53 may include the method of example 51 or some other example herein, wherein the transport block includes multiple SAUs.

Example 54 may include the method of example 46-50 or some other example herein, wherein the DCI schedules transmission of multiple transport blocks.

Example 55 may include the method of example 54 or some other example herein, wherein the resource allocations for individual transport blocks correspond to consecutive time-frequency resources.

Example 56 may include the method of example 54 or some other example herein, wherein the CBGs and/or SAUs of the multiple transport blocks are interlaced with one another in the time domain.

Example 57 may include the method of example 46-56 or some other example herein, wherein respective CBGs include multiple SAUs.

Example 58 may include the method of example 57 or some other example herein, wherein the multiple SAUs are consecutive in the time domain.

Example 59 may include the method of example 57 or some other example herein, wherein the multiple SAUs are interlaced in the time domain with other SAUs of the resource allocation.

Example 60 may include the method of example 46-59, further comprising generating or receiving HARQ feedback for individual CBGs of the resource allocation.

Example 61 may include the method of example 46-60 or some other example herein, wherein the transport block is a PUSCH.

Example 62 may include the method of example 46-60 or some other example herein, wherein the transport block is a PDSCH.

Example 63 may include the method of example 46-62 or some other example herein, wherein the method is performed by a gNB or a portion thereof.

Example 64 may include a method comprising:

encoding, for transmission to a UE, a downlink control information (DCI) to indicate respective resource allocations for two or more transport blocks, wherein the resource allocations include one or more symbol alignment units (SAUs), wherein the SAUs include all time-frequency resources of one or more symbols; and

causing transmission of the transport blocks to the UE or reception of the transport blocks from the UE based on the DCI.

Example 65 may include the method of example 64 or some other example herein, wherein the individual resource allocations include multiple SAUs.

Example 66 may include the method of example 64-65 or some other example herein, wherein the multiple SAUs are consecutive in the time domain.

Example 67 may include the method of example 64-65 or some other example herein, wherein the multiple SAUs are interlaced in the time domain with the SAUs of one or more other resource allocations.

Example 68 may include the method of example 64-67, further comprising generating or receiving HARQ feedback for individual SAUs of the resource allocations.

Example 69 may include the method of example 64-68 or some other example herein, wherein the transport blocks are transmitted on a PUSCH.

Example 70 may include the method of example 64-68 or some other example herein, wherein the transport blocks are transmitted on a PDSCH.

Example 71 may include the method of example 64-70 or some other example herein, wherein the method is performed by a gNB or a portion thereof.

Example 72 may include the method of example 20-71 or some other example herein, wherein the transport block(s) are transmitted on a carrier frequency of greater than 52.6 GHz.

Example B1 may include a method of downlink control channel transmission, wherein method includes:

Semi-static configuration of physical downlink control channel (PDCCH) monitoring occasions using higher layers;

Scheduling of the physical downlink shared channel (PDSCH) using downlink control information (DCI) transmitted in PDCCH configured by higher layer; and

Configuration of additional PDCCH monitoring occasion followed by PDSCH.

Example B2 may include the method of example B1 or some other example herein, wherein additional PDCCH is scheduled in the next symbol after the last symbol of PDSCH.

Example B3 may include the method of example B1 or some other example herein, wherein additional PDCCH is scheduled in the X symbols after the last symbol of PDSCH, wherein X is one, two, three or more symbols depending on configuration.

Example B4 may include the method of example B1 or some other example herein, wherein PDSCH scheduled by additional PDCCH collides with PDCCH monitoring occasion configured by higher layers, UE may assume that PDSCH transmission is prioritized in the corresponding OFDM symbols and potential PDCCH is dropped.

Example B5 may include the method of example B1 or some other example herein, wherein PDSCH scheduled by additional PDCCH collides with PDCCH monitoring occasion configured by higher layers, UE may assume that PDCCH transmission is prioritized in the corresponding OFDM symbols and PDSCH is dropped.

Example B6 may include the method of example B1 or some other example herein, wherein additional PDCCH collides with PDCCH monitoring occasion configured by higher layers, UE may assume that additional PDCCH transmission is prioritized in the corresponding OFDM symbols and PDCCH configured by higher layers is dropped.

Example B7 may include the method of example B1 or some other example herein, wherein additional PDCCH collides with PDCCH monitoring occasion configured by higher layers, UE may assume that additional PDCCH transmission is dropped in the corresponding OFDM symbols and PDCCH configured by higher layers is prioritized.

Example B8 may include the method of example B1 or some other example herein, wherein additional PDCCH collides with PDCCH monitoring occasion configured by higher

layers, UE process additional PDCCH transmission and PDCCH configured by higher layers is prioritized

Example B9 may include the method of example B1 or some other example herein, wherein PDSCH scheduled by additional PDCCH collides with PDCCH monitoring occasion configured by higher layers, UE process PDCCH transmission configured by higher layers and PDSCH scheduled by additional PDCCH.

Example B10 may include the method of example B1 or some other example herein, wherein additional PDCCH may be transmitted after last PDSCH symbol indicated by early termination.

Example B11 may include the method of example B1 or some other example herein, wherein higher layers is RRC or MAC signaling.

Example B12 may include a method comprising:

determining a last symbol of a PDSCH;

determining a PDCCH monitoring occasion for a PDCCH based on the last symbol of the PDSCH; and

monitoring for a PDCCH in the determined PDCCH monitoring occasion.

Example B13 may include the method of example B12 or some other example herein, wherein the PDCCH monitoring occasion includes an earliest symbol after the last symbol of the PDSCH.

Example B14 may include the method of example B12-B13 or some other example herein, wherein the PDCCH monitoring occasion starts in a symbol that is X symbols after the last symbol of the PDSCH.

Example B15 may include the method of example B14 or some other example herein, wherein a value of X is 1, 2, 3, or 4.

Example B16 may include the method of example B14-B15 or some other example herein, further comprising receiving an indication of a value of X.

Example B17 may include the method of example B12-B16 or some other example herein, further comprising receiving the PDCCH.

Example B18 may include the method of example B17 or some other example herein, wherein the PDSCH is a first PDSCH, and wherein the PDCCH schedules a second PDSCH.

Example B19 may include the method of example B12-B18 or some other example herein, wherein the PDCCH monitoring occasion is a first PDCCH monitoring occasion, wherein the second PDSCH collides with a second PDCCH monitoring occasion, and wherein the method further comprises: determining a relative priority of the second PDSCH

compared with the second PDCCH monitoring occasion; and selecting one of decoding the second PDSCH or monitoring for a second PDCCH in the PDCCH monitoring occasion based on the determined relative priority.

Example B20 may include the method of example B19 or some other example herein, wherein the second PDCCH monitoring occasion is configured via RRC signaling.

Example B21 may include the method of example B12-B20 or some other example herein, wherein the PDCCH monitoring occasion is a first PDCCH monitoring occasion, wherein the first PDCCH monitoring occasion overlaps with a second PDCCH monitoring occasion, and wherein the monitoring for the PDCCH in the first PDCCH monitoring occasion is performed based on a relative priority of the first PDCCH monitoring occasion compared with the second PDCCH monitoring occasion.

Example B22 may include the method of example B12-B21 or some other example herein, wherein the PDCCH includes DCI for an uplink or downlink communication.

Example B23 may include the method of example B22 or some other example herein, wherein the communication is on an unlicensed spectrum, in 5G FR2, and/or for ultra-reliable and low-latency communications (URLLC).

Example B24 may include the method of example B12-B23 or some other example herein, wherein the method is performed by a UE or a portion thereof.

Example B25 may include a method comprising:

encoding a PDSCH for transmission;

determining a PDCCH monitoring occasion for a PDCCH based on a last symbol of the PDSCH; and

encoding the PDCCH for transmission in the determined PDCCH monitoring occasion.

Example B26 may include the method of example B25 or some other example herein, wherein the PDCCH monitoring occasion includes an earliest symbol after the last symbol of the PDSCH.

Example B27 may include the method of example B25-B26 or some other example herein, wherein the PDCCH monitoring occasion starts in a symbol that is X symbols after the last symbol of the PDSCH.

Example B28 may include the method of example B27 or some other example herein, wherein a value of X is 1, 2, 3, or 4.

Example B29 may include the method of example B27-B28 or some other example herein, further comprising encoding an indication of a value of X for transmission.

Example B30 may include the method of example B29 or some other example herein, wherein the PDSCH is a first PDSCH, and wherein the PDCCH schedules a second PDSCH.

Example B31 may include the method of example B25-B30 or some other example herein, wherein the PDCCH includes DCI for an uplink communication.

Example B32 may include the method of example B31 or some other example herein, further comprising receiving the uplink communication.

Example B33 may include the method of example B25-B32 or some other example herein, wherein the PDCCH includes DCI to schedule a downlink communication.

Example B34 may include the method of example B33 or some other example herein, further comprising encoding the downlink communication for transmission.

Example B35 may include the method of example B33-B34 or some other example herein, wherein the downlink communication is another PDSCH.

Example B36 may include the method of example B25-B35 or some other example herein, wherein the PDCCH is to schedule a communication on an unlicensed spectrum, in 5G FR2, and/or for ultra-reliable and low-latency communications (URLLC).

Example B37 may include the method of example B25-B36 or some other example herein, wherein the PDSCH and the PDCCH are transmitted to a same UE.

Example B38 may include the method of example B25-B37 or some other example herein, wherein the method is performed by a gNB or a portion thereof.

Example C1 may include one or more non-transitory computer-readable media (NTCRM) having instructions, stored thereon, that when executed by one or more processors, cause a user equipment (UE) to: determine a last symbol of a physical downlink shared channel (PDSCH); determine a physical downlink control channel (PDCCH) monitoring occasion for a PDCCH based on the last symbol of the PDSCH; and monitor for a PDCCH in the determined PDCCH monitoring occasion.

Example C2 may include the one or more NTCRM of example C1 or some other example herein, wherein the PDCCH monitoring occasion starts in a symbol that is a number of one or more symbols after the last symbol of the PDSCH.

Example C3 may include the one or more NTCRM of example C2 or some other example herein, wherein the instructions, when executed, further cause the UE to receive an indication of the number.

Example C4 may include the one or more NTCRM of example C1-C3 or some other example herein, wherein the PDSCH is a first PDSCH, and wherein the instructions, when executed, are further to cause the UE to receive the PDCCH in the PDCCH monitoring

occasion, wherein the PDCCH schedules a second PDSCH or a physical uplink shared channel (PUSCH).

Example C5 may include the one or more NTCRM of example C4 or some other example herein, wherein the PDCCH monitoring occasion is a first PDCCH monitoring occasion, wherein the second PDSCH collides with a second PDCCH monitoring occasion, and wherein the instructions, when executed, are further to cause the UE to: determine a relative priority of the second PDSCH compared with the second PDCCH monitoring occasion; and select one of decoding the second PDSCH or monitoring for another PDCCH in the PDCCH monitoring occasion based on the determined relative priority.

Example C6 may include the one or more NTCRM of example C1-C5 or some other example herein, wherein the PDCCH monitoring occasion is a first PDCCH monitoring occasion, wherein the first PDCCH monitoring occasion overlaps with a second PDCCH monitoring occasion, and wherein the monitoring for the PDCCH in the first PDCCH monitoring occasion is performed based on a relative priority of the first PDCCH monitoring occasion compared with the second PDCCH monitoring occasion.

Example C7 may include the one or more NTCRM of example C1-C6 or some other example herein, wherein the instructions, when executed, are further to cause the UE to receive the PDCCH in the PDCCH monitoring occasion, wherein the PDCCH schedules an uplink or downlink communication in an unlicensed spectrum, in a 5G Frequency Range 2 (FR2), or for ultra-reliable and low-latency communications (URLLC).

Example C8 may include the one or more non-transitory computer-readable media (NTCRM) having instructions, stored thereon, that when executed by one or more processors, cause a next generation NodeB (gNB) to: determine a last symbol of a physical downlink shared channel (PDSCH) transmitted to a user equipment (UE); determine a physical downlink control channel (PDCCH) monitoring occasion for a PDCCH based on the last symbol of the PDSCH; and encode a PDCCH for transmission to the UE in the determined PDCCH monitoring occasion.

Example C9 may include the one or more NTCRM of example C8 or some other example herein, wherein the PDCCH monitoring occasion starts in a symbol that is a number of one or more symbols after the last symbol of the PDSCH.

Example C10 may include the one or more NTCRM of example C9 or some other example herein, wherein the instructions, when executed, further cause the gNB to encode message for transmission to the UE that includes an indication of the number.

Example C11 may include the one or more NTCRM of example C8-C10 or some other example herein, wherein the PDCCH is to schedule a downlink transmission.

Example C12 may include the one or more NTCRM of example C11 or some other example herein, wherein PDSCH is a first PDSCH, and wherein the downlink transmission includes a second PDSCH.

Example C13 may include the one or more NTCRM of example C11 or some other example herein, wherein the PDCCH is to schedule an uplink communication and wherein the instructions, when executed, are further to cause the gNB to receive the uplink communication.

Example C14 may include the one or more NTCRM of example C8-C13 or some other example herein, wherein the instructions, wherein the PDCCH is to schedule an uplink or downlink communication in an unlicensed spectrum, in a 5G Frequency Range 2 (FR2), or for ultra-reliable and low-latency communications (URLLC).

Example C15 may include one or more non-transitory, computer-readable media (NTCRM) having instructions, stored thereon, that when executed by one or more processors cause a user equipment (UE) to: receive a downlink control information (DCI) to indicate a resource allocation for one or more transport blocks, wherein the resource allocation includes one or more symbol alignment units (SAUs); and transmit or receive the one or more transport blocks based on the DCI.

Example C16 may include the one or more NTCRM of example C15 or some other example herein, wherein the resource allocation includes one or more code block groups (CBGs) mapped to one or more SAUs of one or more symbols.

Example C17 may include the one or more NTCRM of example C15-C16 or some other example herein, wherein the SAUs include all time-frequency resources of one or more symbols.

Example C18 may include the one or more NTCRM of example C15-C17 or some other example herein, wherein the DCI includes a start and length indicator value (SLIV) to indicate a time resource of a first SAU of the one or more SAUs.

Example C19 may include the one or more NTCRM of example C16-C18 or some other example herein, wherein the DCI includes a start and length indicator value (SLIV) to indicate a time resource of a first CBG of the one or more CBGs.

Example C20 may include the one or more NTCRM of example C15-C19 or some other example herein, wherein the DCI schedules transmission of multiple transport blocks,

and wherein the resource allocations for individual transport blocks of the multiple transport blocks correspond to consecutive time-frequency resources.

Example C21 may include the one or more NTCRM of any one of examples C16-C20, wherein the DCI schedules transmission of multiple transport blocks, and wherein the resource allocations for individual CBGs of the multiple transport blocks correspond to consecutive time-frequency resources.

Example C22 may include the one or more NTCRM of example C15-C21 or some other example herein, wherein the DCI schedules transmission of multiple transport blocks, and wherein the SAUs of the multiple transport blocks are interlaced with one another in a time domain.

Example C23 may include the one or more NTCRM of any one of example C16-C22, wherein the DCI schedules transmission of multiple transport blocks, and wherein the CBGs of the multiple transport blocks are interlaced with one another in a time domain.

Example Z01 may include an apparatus comprising means to perform one or more elements of a method described in or related to any of examples 1-72, B1-B38, C1-C23, or any other method or process described herein.

Example Z02 may include one or more non-transitory computer-readable media comprising instructions to cause an electronic device, upon execution of the instructions by one or more processors of the electronic device, to perform one or more elements of a method described in or related to any of examples 1-72, B1-B38, C1-C23, or any other method or process described herein.

Example Z03 may include an apparatus comprising logic, modules, or circuitry to perform one or more elements of a method described in or related to any of examples 1-72, B1-B38, C1-C23, or any other method or process described herein.

Example Z04 may include a method, technique, or process as described in or related to any of examples 1-72, B1-B38, C1-C23, or portions or parts thereof.

Example Z05 may include an apparatus comprising: one or more processors and one or more computer-readable media comprising instructions that, when executed by the one or more processors, cause the one or more processors to perform the method, techniques, or process as described in or related to any of examples 1-72, B1-B38, C1-C23, or portions thereof.

Example Z06 may include a signal as described in or related to any of examples 1-72, B1-B38, C1-C23, or portions or parts thereof.

Example Z07 may include a datagram, packet, frame, segment, protocol data unit (PDU), or message as described in or related to any of examples 1-72, B1-B38, C1-C23, or portions or parts thereof, or otherwise described in the present disclosure.

Example Z08 may include a signal encoded with data as described in or related to any of examples 1-72, B1-B38, C1-C23, or portions or parts thereof, or otherwise described in the present disclosure.

Example Z09 may include a signal encoded with a datagram, packet, frame, segment, protocol data unit (PDU), or message as described in or related to any of examples 1-72, B1-B38, C1-C23, or portions or parts thereof, or otherwise described in the present disclosure.

Example Z10 may include an electromagnetic signal carrying computer-readable instructions, wherein execution of the computer-readable instructions by one or more processors is to cause the one or more processors to perform the method, techniques, or process as described in or related to any of examples 1-72, B1-B38, C1-C23, or portions thereof.

Example Z11 may include a computer program comprising instructions, wherein execution of the program by a processing element is to cause the processing element to carry out the method, techniques, or process as described in or related to any of examples 1-72, B1-B38, C1-C23, or portions thereof.

Example Z12 may include a signal in a wireless network as shown and described herein.

Example Z13 may include a method of communicating in a wireless network as shown and described herein.

Example Z14 may include a system for providing wireless communication as shown and described herein.

Example Z15 may include a device for providing wireless communication as shown and described herein.

Any of the above-described examples may be combined with any other example (or combination of examples), unless explicitly stated otherwise. The foregoing description of one or more implementations provides illustration and description, but is not intended to be exhaustive or to limit the scope of embodiments to the precise form disclosed. Modifications and variations are possible in light of the above teachings or may be acquired from practice of various embodiments.

Abbreviations

Unless used differently herein, terms, definitions, and abbreviations may be consistent with terms, definitions, and abbreviations defined in 3GPP TR 21.905 v16.0.0 (2019-06). For the purposes of the present document, the following abbreviations may apply to the examples and embodiments discussed herein.

3GPP Third Generation Partnership Project
4G Fourth Generation
5G Fifth Generation
5GC 5G Core network
ACK Acknowledgement
AF Application Function
AM Acknowledged Mode
AMBR Aggregate Maximum Bit Rate
AMF Access and Mobility Management Function
AN Access Network
ANR Automatic Neighbour Relation
AP Application Protocol, Antenna Port, Access Point
API Application Programming Interface
APN Access Point Name
ARP Allocation and Retention Priority
ARQ Automatic Repeat Request
AS Access Stratum
ASN.1 Abstract Syntax Notation One
AUSF Authentication Server Function
AWGN Additive White Gaussian Noise
BAP Backhaul Adaptation Protocol
BCH Broadcast Channel
BER Bit Error Ratio
BFD Beam Failure Detection
BLER Block Error Rate
BPSK Binary Phase Shift Keying
BRAS Broadband Remote Access Server
BSS Business Support System
BS Base Station
BSR Buffer Status Report
BW Bandwidth
BWP Bandwidth Part
C-RNTI Cell Radio Network Temporary Identity
CA Carrier Aggregation, Certification Authority
CAPEX CAPital EXpenditure
CBRA Contention Based Random Access
CC Component Carrier, Country Code, Cryptographic Checksum
CCA Clear Channel Assessment
CCE Control Channel Element
CCCH Common Control Channel
CE Coverage Enhancement
CDM Content Delivery Network
CDMA Code-Division Multiple Access
CFRA Contention Free Random Access
CG Cell Group
CI Cell Identity
CID Cell-ID (e.g., positioning method)
CIM Common Information Model
CIR Carrier to Interference Ratio
CK Cipher Key
CM Connection Management,

Conditional Mandatory
CMAS Commercial Mobile Alert Service
CMD Command
CMS Cloud Management System
CO Conditional Optional
CoMP Coordinated Multi-Point
CORESET Control Resource Set
COTS Commercial Off-The-Shelf
CP Control Plane, Cyclic Prefix, Connection Point
CPD Connection Point Descriptor
CPE Customer Premise Equipment
CPICH Common Pilot Channel
CQI Channel Quality Indicator
CPU CSI processing unit, Central Processing Unit
C/R Command/Response field bit
CRAN Cloud Radio Access Network, Cloud RAN
CRB Common Resource Block
CRC Cyclic Redundancy Check
CRI Channel-State Information Resource Indicator, CSI-RS Resource Indicator
C-RNTI Cell RNTI
CS Circuit Switched
CSAR Cloud Service Archive
CSI Channel-State Information
CSI-IM CSI Interference Measurement
CSI-RS CSI Reference Signal
CSI-RSRP CSI reference signal received power
CSI-RSRQ CSI reference signal received quality
CSI-SINR CSI signal-to-noise and interference ratio
CSMA Carrier Sense Multiple Access
CSMA/CA CSMA with collision avoidance
CSS Common Search Space, Cell-specific Search Space
CTS Clear-to-Send
CW Codeword
CWS Contention Window Size
D2D Device-to-Device
DC Dual Connectivity, Direct Current
DCI Downlink Control Information
DF Deployment Flavour
DL Downlink
DMTF Distributed Management Task Force
DPDK Data Plane Development Kit
DM-RS, DMRS Demodulation Reference Signal
DN Data network
DRB Data Radio Bearer
DRS Discovery Reference Signal
DRX Discontinuous Reception
DSL Domain Specific Language. Digital Subscriber Line

DSLAM DSL Access Multiplexer
DwPTS Downlink Pilot Time Slot
E-LAN Ethernet Local Area Network
E2E End-to-End
ECCA extended clear channel assessment, extended CCA
ECCE Enhanced Control Channel Element, Enhanced CCE
ED Energy Detection
EDGE Enhanced Datarates for GSM Evolution (GSM Evolution)
EGMF Exposure Governance Management Function
EGPRS Enhanced GPRS
EIR Equipment Identity Register
eLAA enhanced Licensed Assisted Access, enhanced LAA
EM Element Manager
eMBB Enhanced Mobile Broadband
EMS Element Management System
eNB evolved NodeB, E-UTRAN Node B
EN-DC E-UTRA-NR Dual Connectivity
EPC Evolved Packet Core
EPDCCH enhanced PDCCH, enhanced Physical Downlink Control Cannel
EPRE Energy per resource element
EPS Evolved Packet System
EREG enhanced REG, enhanced resource element groups
ETSI European Telecommunications Standards Institute
ETWS Earthquake and Tsunami Warning System
eUICC embedded UICC, embedded Universal Integrated Circuit Card
E-UTRA Evolved UTRA
E-UTRAN Evolved UTRAN
EV2X Enhanced V2X
F1AP F1 Application Protocol
F1-C F1 Control plane interface
F1-U F1 User plane interface
FACCH Fast Associated Control CHannel
FACCH/F Fast Associated Control Channel/Full rate
FACCH/H Fast Associated Control Channel/Half rate
FACH Forward Access Channel
FAUSCH Fast Uplink Signalling Channel
FB Functional Block
FBI Feedback Information
FCC Federal Communications Commission
FCCH Frequency Correction CHannel
FDD Frequency Division Duplex

FDM Frequency Division Multiplex
FDMA Frequency Division Multiple Access
FE Front End
FEC Forward Error Correction
FFS For Further Study
FFT Fast Fourier Transformation
feLAA further enhanced Licensed Assisted Access, further enhanced LAA
FN Frame Number
FPGA Field-Programmable Gate Array
FR Frequency Range
G-RNTI GERAN Radio Network Temporary Identity
GERAN GSM EDGE RAN, GSM EDGE Radio Access Network
GGSN Gateway GPRS Support Node
GLONASS GLObal'naya NAvigatsionnaya Sputnikovaya Sistema (Engl.: Global Navigation Satellite System)
gNB Next Generation NodeB
gNB-CU gNB-centralized unit, Next Generation NodeB centralized unit
gNB-DU gNB-distributed unit, Next Generation NodeB distributed unit
GNSS Global Navigation Satellite System
GPRS General Packet Radio Service
GSM Global System for Mobile Communications, Groupe Spécial Mobile
GTP GPRS Tunneling Protocol
GTP-U GPRS Tunnelling Protocol for User Plane
GTS Go To Sleep Signal (related to WUS)
GUMMEI Globally Unique MME Identifier
GUTI Globally Unique Temporary UE Identity
HARQ Hybrid ARQ, Hybrid Automatic Repeat Request
HANDO Handover
HFN HyperFrame Number
HHO Hard Handover
HLR Home Location Register
HN Home Network
HO Handover
HPLMN Home Public Land Mobile Network
HSDPA High Speed Downlink Packet Access
HSN Hopping Sequence Number
HSPA High Speed Packet Access
HSS Home Subscriber Server
HSUPA High Speed Uplink Packet Access
HTTP Hyper Text Transfer Protocol
HTTPS Hyper Text Transfer Protocol Secure (https is

http/1.1 over SSL, i.e. port 443)
I-Block Information Block
ICCID Integrated Circuit Card Identification
IAB Integrated Access and Backhaul
ICIC Inter-Cell Interference Coordination
ID Identity, identifier
IDFT Inverse Discrete Fourier Transform
IE Information element
IBE In-Band Emission
IEEE Institute of Electrical and Electronics Engineers
IEI Information Element Identifier
IEIDL Information Element Identifier Data Length
IETF Internet Engineering Task Force
IF Infrastructure
IM Interference Measurement, Intermodulation, IP Multimedia
IMC IMS Credentials
IMEI International Mobile Equipment Identity
IMGI International mobile group identity
IMPI IP Multimedia Private Identity
IMPU IP Multimedia PUblic identity
IMS IP Multimedia Subsystem
IMSI International Mobile Subscriber Identity
IoT Internet of Things
IP Internet Protocol
Ipsec IP Security, Internet Protocol Security
IP-CAN IP-Connectivity Access Network
IP-M IP Multicast
IPv4 Internet Protocol Version 4
IPv6 Internet Protocol Version 6
IR Infrared
IS In Sync
IRP Integration Reference Point
ISDN Integrated Services Digital Network
ISIM IM Services Identity Module
ISO International Organisation for Standardisation
ISP Internet Service Provider
IWF Interworking-Function
I-WLAN Interworking WLAN
Constraint length of the convolutional code, USIM Individual key
kB Kilobyte (1000 bytes)
kbps kilo-bits per second
Kc Ciphering key
Ki Individual subscriber authentication key
KPI Key Performance Indicator
KQI Key Quality Indicator
KSI Key Set Identifier
ksps kilo-symbols per second

KVM Kernel Virtual Machine
L1 Layer 1 (physical layer)
L1-RSRP Layer 1 reference signal received power
L2 Layer 2 (data link layer)
L3 Layer 3 (network layer)
LAA Licensed Assisted Access
LAN Local Area Network
LBT Listen Before Talk
LCM LifeCycle Management
LCR Low Chip Rate
LCS Location Services
LCID Logical Channel ID
LI Layer Indicator
LLC Logical Link Control, Low Layer Compatibility
LPLMN Local PLMN
LPP LTE Positioning Protocol
LSB Least Significant Bit
LTE Long Term Evolution
LWA LTE-WLAN aggregation
LWIP LTE/WLAN Radio Level Integration with IPsec Tunnel
LTE Long Term Evolution
M2M Machine-to-Machine
MAC Medium Access Control (protocol layering context)
MAC Message authentication code (security/encryption context)
MAC-A MAC used for authentication and key agreement (TSG T WG3 context)
MAC-IMAC used for data integrity of signalling messages (TSG T WG3 context)
MANO Management and Orchestration
MBMS Multimedia Broadcast and Multicast Service
MBSFN Multimedia Broadcast multicast service Single Frequency Network
MCC Mobile Country Code
MCG Master Cell Group
MCOT Maximum Channel Occupancy Time
MCS Modulation and coding scheme
MDAF Management Data Analytics Function
MDAS Management Data Analytics Service
MDT Minimization of Drive Tests
ME Mobile Equipment
MeNB master eNB
MER Message Error Ratio
MGL Measurement Gap Length
MGRP Measurement Gap Repetition Period
MIB Master Information Block, Management Information Base
MIMO Multiple Input Multiple Output

MLC Mobile Location Centre
MM Mobility Management
MME Mobility Management Entity
MN Master Node
MnS Management Service
MO Measurement Object, Mobile Originated
MPBCH MTC Physical Broadcast CHannel
MPDCCH MTC Physical Downlink Control CHannel
MPDSCH MTC Physical Downlink Shared CHannel
MPRACH MTC Physical Random Access CHannel
MPUSCH MTC Physical Uplink Shared Channel
MPLS MultiProtocol Label Switching
MS Mobile Station
MSB Most Significant Bit
MSC Mobile Switching Centre
MSI Minimum System Information, MCH Scheduling Information
MSID Mobile Station Identifier
MSIN Mobile Station Identification Number
MSISDN Mobile Subscriber ISDN Number
MT Mobile Terminated, Mobile Termination
MTC Machine-Type Communications
mMTC massive MTC, massive Machine-Type Communications
MU-MIMO Multi User MIMO
MWUS MTC wake-up signal, MTC WUS
NACK Negative Acknowledgement
NAI Network Access Identifier
NAS Non-Access Stratum, Non- Access Stratum layer
NCT Network Connectivity Topology
NC-JT Non-Coherent Joint Transmission
NEC Network Capability Exposure
NE-DC NR-E-UTRA Dual Connectivity
NEF Network Exposure Function
NF Network Function
NFP Network Forwarding Path
NFPD Network Forwarding Path Descriptor
NFV Network Functions Virtualization
NFVI NFV Infrastructure
NFVO NFV Orchestrator
NG Next Generation, Next Gen
NGEN-DC NG-RAN E-UTRA-NR Dual Connectivity
NM Network Manager
NMS Network Management System
N-PoP Network Point of Presence
NMIB, N-MIB Narrowband MIB

NPBCH Narrowband Physical Broadcast CHannel
NPDCCH Narrowband Physical Downlink Control CHannel
NPDSCH Narrowband Physical Downlink Shared CHannel
NPRACH Narrowband Physical Random Access CHannel
NPUSCH Narrowband Physical Uplink Shared CHannel
NPSS Narrowband Primary Synchronization Signal
NSSS Narrowband Secondary Synchronization Signal
NR New Radio,
Neighbour Relation
NRF NF Repository Function
NRS Narrowband Reference Signal
NS Network Service
NSA Non-Standalone operation mode
NSD Network Service Descriptor
NSR Network Service Record
NSSAI Network Slice Selection Assistance Information
S-NNSAI Single-NSSAI
NSSF Network Slice Selection Function
NW Network
NWUS Narrowband wake-up signal, Narrowband WUS
NZP Non-Zero Power
O&M Operation and Maintenance
ODU2 Optical channel Data Unit - type 2
OFDM Orthogonal Frequency Division Multiplexing
OFDMA Orthogonal Frequency Division Multiple Access
OOB Out-of-band
OOS Out of Sync
OPEX OPerating EXpense
OSI Other System Information
OSS Operations Support System
OTA over-the-air
PAPR Peak-to-Average Power Ratio
PAR Peak to Average Ratio
PBCH Physical Broadcast Channel
PC Power Control, Personal Computer
PCC Primary Component Carrier, Primary CC
PCell Primary Cell
PCI Physical Cell ID, Physical Cell Identity
PCEF Policy and Charging Enforcement Function
PCF Policy Control Function
PCRF Policy Control and Charging Rules Function
PDCP Packet Data Convergence Protocol, Packet Data Convergence Protocol layer

PDCCH Physical Downlink Control Channel
PDCP Packet Data Convergence Protocol
PDN Packet Data Network, Public Data Network
PDSCH Physical Downlink Shared Channel
PDU Protocol Data Unit
PEI Permanent Equipment Identifiers
PFD Packet Flow Description
P-GW PDN Gateway
PHICH Physical hybrid-ARQ indicator channel
PHY Physical layer
PLMN Public Land Mobile Network
PIN Personal Identification Number
PM Performance Measurement
PMI Precoding Matrix Indicator
PNF Physical Network Function
PNFD Physical Network Function Descriptor
PNFR Physical Network Function Record
POC PTT over Cellular
PP, PTP Point-to-Point
PPP Point-to-Point Protocol
PRACH Physical RACH
PRB Physical resource block
PRG Physical resource block group
ProSe Proximity Services, Proximity-Based Service
PRS Positioning Reference Signal
PRR Packet Reception Radio
PS Packet Services
PSBCH Physical Sidelink Broadcast Channel
PSDCH Physical Sidelink Downlink Channel
PSCCH Physical Sidelink Control Channel
PSFCH Physical Sidelink Feedback Channel
PSSCH Physical Sidelink Shared Channel
PSCell Primary SCell
PSS Primary Synchronization Signal
PSTN Public Switched Telephone Network
PT-RS Phase-tracking reference signal
PTT Push-to-Talk
PUCCH Physical Uplink Control Channel
PUSCH Physical Uplink Shared Channel
QAM Quadrature Amplitude Modulation
QCI QoS class of identifier
QCL Quasi co-location
QFI QoS Flow ID, QoS Flow Identifier
QoS Quality of Service
QPSK Quadrature (Quaternary) Phase Shift Keying
QZSS Quasi-Zenith Satellite System
RA-RNTI Random Access RNTI

RAB Radio Access Bearer, Random Access Burst
RACH Random Access Channel
RADIUS Remote Authentication Dial In User Service
RAN Radio Access Network
RAND RANDom number (used for authentication)
RAR Random Access Response
RAT Radio Access Technology
RAU Routing Area Update
RB Resource block, Radio Bearer
RBG Resource block group
REG Resource Element Group
Rel Release
REQ REQuest
RF Radio Frequency
RI Rank Indicator
RIV Resource indicator value
RL Radio Link
RLC Radio Link Control, Radio Link Control layer
RLC AM RLC Acknowledged Mode
RLC UM RLC Unacknowledged Mode
RLF Radio Link Failure
RLM Radio Link Monitoring
RLM-RS Reference Signal for RLM
RM Registration Management
RMC Reference Measurement Channel
RMSI Remaining MSI, Remaining Minimum System Information
RN Relay Node
RNC Radio Network Controller
RNL Radio Network Layer
RNTI Radio Network Temporary Identifier
ROHC RObust Header Compression
RRC Radio Resource Control, Radio Resource Control layer
RRM Radio Resource Management
RS Reference Signal
RSRP Reference Signal Received Power
RSRQ Reference Signal Received Quality
RSSI Received Signal Strength Indicator
RSU Road Side Unit
RSTD Reference Signal Time difference
RTP Real Time Protocol
RTS Ready-To-Send
RTT Round Trip Time
Rx Reception, Receiving, Receiver
S1AP S1 Application Protocol
S1-MME S1 for the control plane
S1-U S1 for the user plane
S-GW Serving Gateway
S-RNTI SRNC Radio Network Temporary Identity
S-TMSI SAE Temporary Mobile Station Identifier
SA Standalone operation mode

SAE System Architecture Evolution
SAP Service Access Point
SAPD Service Access Point Descriptor
SAPI Service Access Point Identifier
SCC Secondary Component Carrier, Secondary CC
SCell Secondary Cell
SC-FDMA Single Carrier Frequency Division Multiple Access
SCG Secondary Cell Group
SCM Security Context Management
SCS Subcarrier Spacing
SCTP Stream Control Transmission Protocol
SDAP Service Data Adaptation Protocol, Service Data Adaptation Protocol layer
SDL Supplementary Downlink
SDNF Structured Data Storage Network Function
SDP Session Description Protocol
SDSF Structured Data Storage Function
SDU Service Data Unit
SEAF Security Anchor Function
SeNB secondary eNB
SEPP Security Edge Protection Proxy
SFI Slot format indication
SFTD Space-Frequency Time Diversity, SFN and frame timing difference
SFN System Frame Number
SgNB Secondary gNB
SGSN Serving GPRS Support Node
S-GW Serving Gateway
SI System Information
SI-RNTI System Information RNTI
SIB System Information Block
SIM Subscriber Identity Module
SIP Session Initiated Protocol
SiP System in Package
SL Sidelink
SLA Service Level Agreement
SM Session Management
SMF Session Management Function
SMS Short Message Service
SMSF SMS Function
SMTC SSB-based Measurement Timing Configuration
SN Secondary Node, Sequence Number
SoC System on Chip
SON Self-Organizing Network
SpCell Special Cell
SP-CSI-RNTISemi-Persistent CSI RNTI
SPS Semi-Persistent Scheduling
SQN Sequence number
SR Scheduling Request
SRB Signalling Radio Bearer
SRS Sounding Reference Signal
SS Synchronization Signal
SSB SS Block

SSBRI SSB Resource Indicator
SSC Session and Service Continuity
SS-RSRP Synchronization Signal based Reference Signal Received Power
SS-RSRQ Synchronization Signal based Reference Signal Received Quality
SS-SINR Synchronization Signal based Signal to Noise and Interference Ratio
SSS Secondary Synchronization Signal
SSSG Search Space Set Group
SSSIF Search Space Set Indicator
SST Slice/Service Types
SU-MIMO Single User MIMO
SUL Supplementary Uplink
TA Timing Advance, Tracking Area
TAC Tracking Area Code
TAG Timing Advance Group
TAU Tracking Area Update
TB Transport Block
TBS Transport Block Size
TBD To Be Defined
TCI Transmission Configuration Indicator
TCP Transmission Communication Protocol
TDD Time Division Duplex
TDM Time Division Multiplexing
TDMA Time Division Multiple Access
TE Terminal Equipment
TEID Tunnel End Point Identifier
TFT Traffic Flow Template
TMSI Temporary Mobile Subscriber Identity
TNL Transport Network Layer
TPC Transmit Power Control
TPMI Transmitted Precoding Matrix Indicator
TR Technical Report
TRP, TRxP Transmission Reception Point
TRS Tracking Reference Signal
TRx Transceiver
TS Technical Specifications, Technical Standard
TTI Transmission Time Interval
Tx Transmission, Transmitting, Transmitter
U-RNTI UTRAN Radio Network Temporary Identity
UART Universal Asynchronous Receiver and Transmitter
UCI Uplink Control Information
UE User Equipment
UDM Unified Data Management
UDP User Datagram Protocol

UDR Unified Data Repository
UDSF Unstructured Data Storage Network Function
UICC Universal Integrated Circuit Card
UL Uplink
UM Unacknowledged Mode
UML Unified Modelling Language
UMTS Universal Mobile Telecommunications System
UP User Plane
UPF User Plane Function
URI Uniform Resource Identifier
URL Uniform Resource Locator
URLLC Ultra-Reliable and Low Latency
USB Universal Serial Bus
USIM Universal Subscriber Identity Module
USS UE-specific search space
UTRA UMTS Terrestrial Radio Access
UTRAN Universal Terrestrial Radio Access Network
UwPTS Uplink Pilot Time Slot
V2I Vehicle-to-Infrastruction
V2P Vehicle-to-Pedestrian
V2V Vehicle-to-Vehicle
V2X Vehicle-to-everything
VIM Virtualized Infrastructure Manager
VL Virtual Link,
VLAN Virtual LAN, Virtual Local Area Network
VM Virtual Machine
VNF Virtualized Network Function
VNFFG VNF Forwarding Graph
VNFFGD VNF Forwarding Graph Descriptor
VNFM VNF Manager
VoIP Voice-over-IP, Voice-over-Internet Protocol
VPLMN Visited Public Land Mobile Network
VPN Virtual Private Network
VRB Virtual Resource Block
WiMAX Worldwide Interoperability for Microwave Access
WLANWireless Local Area Network
WMAN Wireless Metropolitan Area Network
WPANWireless Personal Area Network
X2-C X2-Control plane
X2-U X2-User plane
XML eXtensible Markup Language
XRES EXpected user RESponse
XOR eXclusive OR
ZC Zadoff-Chu
ZP Zero Power

Terminology

For the purposes of the present document, the following terms and definitions are applicable to the examples and embodiments discussed herein.

The term "circuitry" as used herein refers to, is part of, or includes hardware components such as an electronic circuit, a logic circuit, a processor (shared, dedicated, or group) and/or memory (shared, dedicated, or group), an Application Specific Integrated Circuit (ASIC), a field-programmable device (FPD) (e.g., a field-programmable gate array (FPGA), a programmable logic device (PLD), a complex PLD (CPLD), a high-capacity PLD (HCPLD), a structured ASIC, or a programmable SoC), digital signal processors (DSPs), etc., that are configured to provide the described functionality. In some embodiments, the circuitry may execute one or more software or firmware programs to provide at least some of the described functionality. The term "circuitry" may also refer to a combination of one or more hardware elements (or a combination of circuits used in an electrical or electronic system) with the program code used to carry out the functionality of that program code. In these embodiments, the combination of hardware elements and program code may be referred to as a particular type of circuitry.

The term "processor circuitry" as used herein refers to, is part of, or includes circuitry capable of sequentially and automatically carrying out a sequence of arithmetic or logical operations, or recording, storing, and/or transferring digital data. Processing circuitry may include one or more processing cores to execute instructions and one or more memory structures to store program and data information. The term "processor circuitry" may refer to one or more application processors, one or more baseband processors, a physical central processing unit (CPU), a single-core processor, a dual-core processor, a triple-core processor, a quad-core processor, and/or any other device capable of executing or otherwise operating computer-executable instructions, such as program code, software modules, and/or functional processes. Processing circuitry may include more hardware accelerators, which may be microprocessors, programmable processing devices, or the like. The one or more hardware accelerators may include, for example, computer vision (CV) and/or deep learning (DL) accelerators. The terms "application circuitry" and/or "baseband circuitry" may be considered synonymous to, and may be referred to as, "processor circuitry."

The term "interface circuitry" as used herein refers to, is part of, or includes circuitry that enables the exchange of information between two or more components or devices. The term "interface circuitry" may refer to one or more hardware interfaces, for example, buses, I/O interfaces, peripheral component interfaces, network interface cards, and/or the like.

The term "user equipment" or "UE" as used herein refers to a device with radio communication capabilities and may describe a remote user of network resources in a communications network. The term "user equipment" or "UE" may be considered synonymous to, and may be referred to as, client, mobile, mobile device, mobile terminal, user terminal, mobile unit, mobile station, mobile user, subscriber, user, remote station, access agent, user agent, receiver, radio equipment, reconfigurable radio equipment, reconfigurable mobile device, etc. Furthermore, the term "user equipment" or "UE" may include any type of wireless/wired device or any computing device including a wireless communications interface.

The term "network element" as used herein refers to physical or virtualized equipment and/or infrastructure used to provide wired or wireless communication network services. The term "network element" may be considered synonymous to and/or referred to as a networked computer, networking hardware, network equipment, network node, router, switch, hub, bridge, radio network controller, RAN device, RAN node, gateway, server, virtualized VNF, NFVI, and/or the like.

The term "computer system" as used herein refers to any type interconnected electronic devices, computer devices, or components thereof. Additionally, the term "computer system" and/or "system" may refer to various components of a computer that are communicatively coupled with one another. Furthermore, the term "computer system" and/or "system" may refer to multiple computer devices and/or multiple computing systems that are communicatively coupled with one another and configured to share computing and/or networking resources.

The term "appliance," "computer appliance," or the like, as used herein refers to a computer device or computer system with program code (e.g., software or firmware) that is specifically designed to provide a specific computing resource. A "virtual appliance" is a virtual machine image to be implemented by a hypervisor-equipped device that virtualizes or emulates a computer appliance or otherwise is dedicated to provide a specific computing resource.

The term "resource" as used herein refers to a physical or virtual device, a physical or virtual component within a computing environment, and/or a physical or virtual component within a particular device, such as computer devices, mechanical devices, memory space, processor/CPU time, processor/CPU usage, processor and accelerator loads, hardware time or usage, electrical power, input/output operations, ports or network sockets, channel/link allocation, throughput, memory usage, storage, network, database and applications, workload

units, and/or the like. A "hardware resource" may refer to compute, storage, and/or network resources provided by physical hardware element(s). A "virtualized resource" may refer to compute, storage, and/or network resources provided by virtualization infrastructure to an application, device, system, etc. The term "network resource" or "communication resource" may refer to resources that are accessible by computer devices/systems via a communications network. The term "system resources" may refer to any kind of shared entities to provide services, and may include computing and/or network resources. System resources may be considered as a set of coherent functions, network data objects or services, accessible through a server where such system resources reside on a single host or multiple hosts and are clearly identifiable.

The term "channel" as used herein refers to any transmission medium, either tangible or intangible, which is used to communicate data or a data stream. The term "channel" may be synonymous with and/or equivalent to "communications channel," "data communications channel," "transmission channel," "data transmission channel," "access channel," "data access channel," "link," "data link," "carrier," "radiofrequency carrier," and/or any other like term denoting a pathway or medium through which data is communicated. Additionally, the term "link" as used herein refers to a connection between two devices through a RAT for the purpose of transmitting and receiving information.

The terms "instantiate," "instantiation," and the like as used herein refers to the creation of an instance. An "instance" also refers to a concrete occurrence of an object, which may occur, for example, during execution of program code.

The terms "coupled," "communicatively coupled," along with derivatives thereof are used herein. The term "coupled" may mean two or more elements are in direct physical or electrical contact with one another, may mean that two or more elements indirectly contact each other but still cooperate or interact with each other, and/or may mean that one or more other elements are coupled or connected between the elements that are said to be coupled with each other. The term "directly coupled" may mean that two or more elements are in direct contact with one another. The term "communicatively coupled" may mean that two or more elements may be in contact with one another by a means of communication including through a wire or other interconnect connection, through a wireless communication channel or link, and/or the like.

The term "information element" refers to a structural element containing one or more fields. The term "field" refers to individual contents of an information element, or a data element that contains content.

The term "SMTC" refers to an SSB-based measurement timing configuration configured by *SSB-MeasurementTimingConfiguration*.

The term "SSB" refers to an SS/PBCH block.

The term "a "Primary Cell" refers to the MCG cell, operating on the primary frequency, in which the UE either performs the initial connection establishment procedure or initiates the connection re-establishment procedure.

The term "Primary SCG Cell" refers to the SCG cell in which the UE performs random access when performing the Reconfiguration with Sync procedure for DC operation.

The term "Secondary Cell" refers to a cell providing additional radio resources on top of a Special Cell for a UE configured with CA.

The term "Secondary Cell Group" refers to the subset of serving cells comprising the PSCell and zero or more secondary cells for a UE configured with DC.

The term "Serving Cell" refers to the primary cell for a UE in RRC_CONNECTED not configured with CA/DC there is only one serving cell comprising of the primary cell.

The term "serving cell" or "serving cells" refers to the set of cells comprising the Special Cell(s) and all secondary cells for a UE in RRC_CONNECTED configured with CA/.

The term "Special Cell" refers to the PCell of the MCG or the PSCell of the SCG for DC operation; otherwise, the term "Special Cell" refers to the Pcell.

CLAIMS

What is claimed is:

1. One or more non-transitory computer-readable media (NTCRM) having instructions, stored thereon, that when executed by one or more processors, cause a user equipment (UE) to:

determine a last symbol of a physical downlink shared channel (PDSCH);

determine a physical downlink control channel (PDCCH) monitoring occasion for a PDCCH based on the last symbol of the PDSCH; and

monitor for a PDCCH in the determined PDCCH monitoring occasion.

2. The one or more NTCRM of claim 1, wherein the PDCCH monitoring occasion starts in a symbol that is a number of one or more symbols after the last symbol of the PDSCH.

3. The one or more NTCRM of claim 2, wherein the instructions, when executed, further cause the UE to receive an indication of the number.

4. The one or more NTCRM of any one of claims 1-3, wherein the PDSCH is a first PDSCH, and wherein the instructions, when executed, are further to cause the UE to receive the PDCCH in the PDCCH monitoring occasion, wherein the PDCCH schedules a second PDSCH or a physical uplink shared channel (PUSCH).

5. The one or more NTCRM of claim 4, wherein the PDCCH monitoring occasion is a first PDCCH monitoring occasion, wherein the second PDSCH collides with a second PDCCH monitoring occasion, and wherein the instructions, when executed, are further to cause the UE to:

determine a relative priority of the second PDSCH compared with the second PDCCH monitoring occasion; and

select one of decoding the second PDSCH or monitoring for another PDCCH in the PDCCH monitoring occasion based on the determined relative priority.

6. The one or more NTCRM of any one of claims 1-5, wherein the PDCCH monitoring occasion is a first PDCCH monitoring occasion, wherein the first PDCCH

monitoring occasion overlaps with a second PDCCH monitoring occasion, and wherein the monitoring for the PDCCH in the first PDCCH monitoring occasion is performed based on a relative priority of the first PDCCH monitoring occasion compared with the second PDCCH monitoring occasion.

7. The one or more NTCRM of any one of claims 1-6, wherein the instructions, when executed, are further to cause the UE to receive the PDCCH in the PDCCH monitoring occasion, wherein the PDCCH schedules an uplink or downlink communication in an unlicensed spectrum, in a 5G Frequency Range 2 (FR2), or for ultra-reliable and low-latency communications (URLLC).

8. One or more non-transitory computer-readable media (NTCRM) having instructions, stored thereon, that when executed by one or more processors, cause a next generation NodeB (gNB) to:

determine a last symbol of a physical downlink shared channel (PDSCH) transmitted to a user equipment (UE);

determine a physical downlink control channel (PDCCH) monitoring occasion for a PDCCH based on the last symbol of the PDSCH; and

encode a PDCCH for transmission to the UE in the determined PDCCH monitoring occasion.

9. The one or more NTCRM of claim 8, wherein the PDCCH monitoring occasion starts in a symbol that is a number of one or more symbols after the last symbol of the PDSCH.

10. The one or more NTCRM of claim 9, wherein the instructions, when executed, further cause the gNB to encode message for transmission to the UE that includes an indication of the number.

11. The one or more NTCRM of any one of claims 8-10, wherein the PDCCH is to schedule a downlink transmission.

12. The one or more NTCRM of claim 11, wherein PDSCH is a first PDSCH, and wherein the downlink transmission includes a second PDSCH.

13. The one or more NTCRM of claim 11, wherein the PDCCH is to schedule an uplink communication and wherein the instructions, when executed, are further to cause the gNB to receive the uplink communication.

14. The one or more NTCRM of any one of claims 8-13, wherein the instructions, wherein the PDCCH is to schedule an uplink or downlink communication in an unlicensed spectrum, in a 5G Frequency Range 2 (FR2), or for ultra-reliable and low-latency communications (URLLC).

15. One or more non-transitory, computer-readable media (NTCRM) having instructions, stored thereon, that when executed by one or more processors cause a user equipment (UE) to:

receive a downlink control information (DCI) to indicate a resource allocation for one or more transport blocks, wherein the resource allocation includes one or more symbol alignment units (SAUs); and

transmit or receive the one or more transport blocks based on the DCI.

16. The one or more NTCRM of claim 15, wherein the resource allocation includes one or more code block groups (CBGs) mapped to one or more SAUs of one or more symbols.

17. The one or more NTCRM of any one of claims 15-16, wherein the SAUs include all time-frequency resources of one or more symbols.

18. The one or more NTCRM of any one of claims 15-17, wherein the DCI includes a start and length indicator value (SLIV) to indicate a time resource of a first SAU of the one or more SAUs.

19. The one or more NTCRM of any one of claims 16-18, wherein the DCI includes a start and length indicator value (SLIV) to indicate a time resource of a first CBG of the one or more CBGs.

20. The one or more NTCRM of any one of claims 15-19, wherein the DCI schedules transmission of multiple transport blocks, and wherein the resource allocations for individual transport blocks of the multiple transport blocks correspond to consecutive time-frequency resources.

21. The one or more NTCRM of any one of claims 16-20, wherein the DCI schedules transmission of multiple transport blocks, and wherein the resource allocations for individual CBGs of the multiple transport blocks correspond to consecutive time-frequency resources.

22. The one or more NTCRM of any one of claims 15-21, wherein the DCI schedules transmission of multiple transport blocks, and wherein the SAUs of the multiple transport blocks are interlaced with one another in a time domain.

23. The one or more NTCRM of any one of claims 16-22, wherein the DCI schedules transmission of multiple transport blocks, and wherein the CBGs of the multiple transport blocks are interlaced with one another in a time domain.

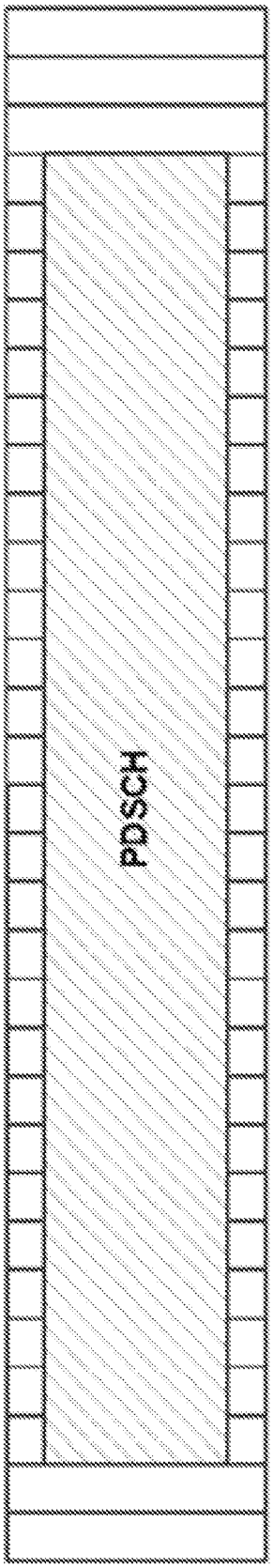


Figure 1. Long PDSCH transmission duration

Figure 1

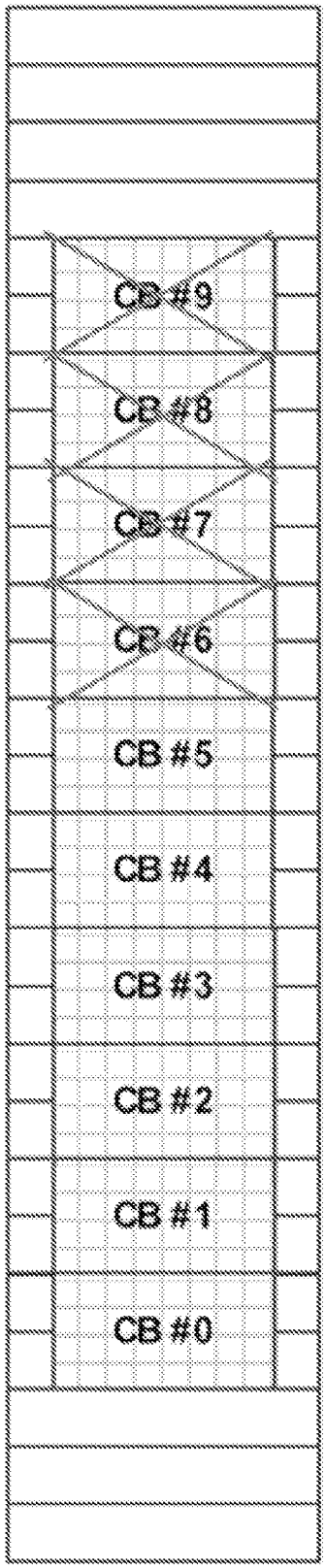


Figure 2. Early termination of PDSCH transmission

Figure 2

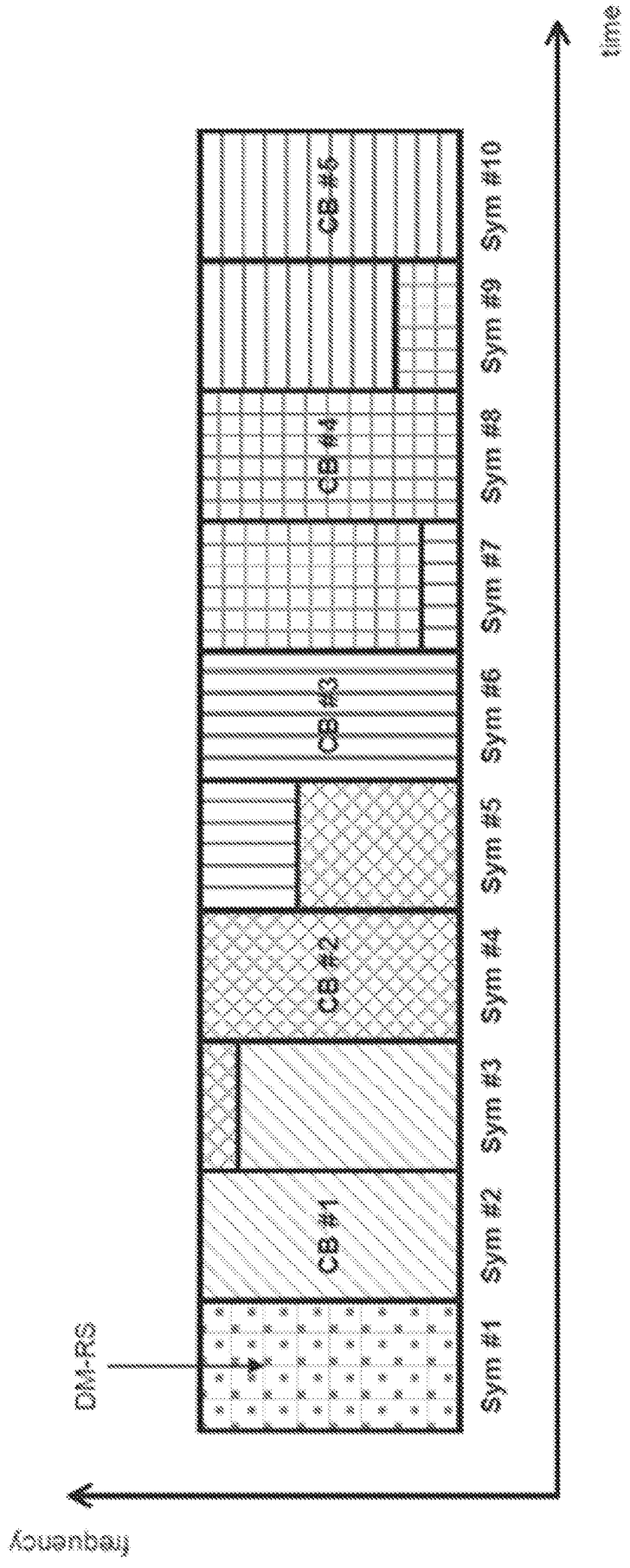


Figure 3. CB to time/frequency resource mapping

Figure 3

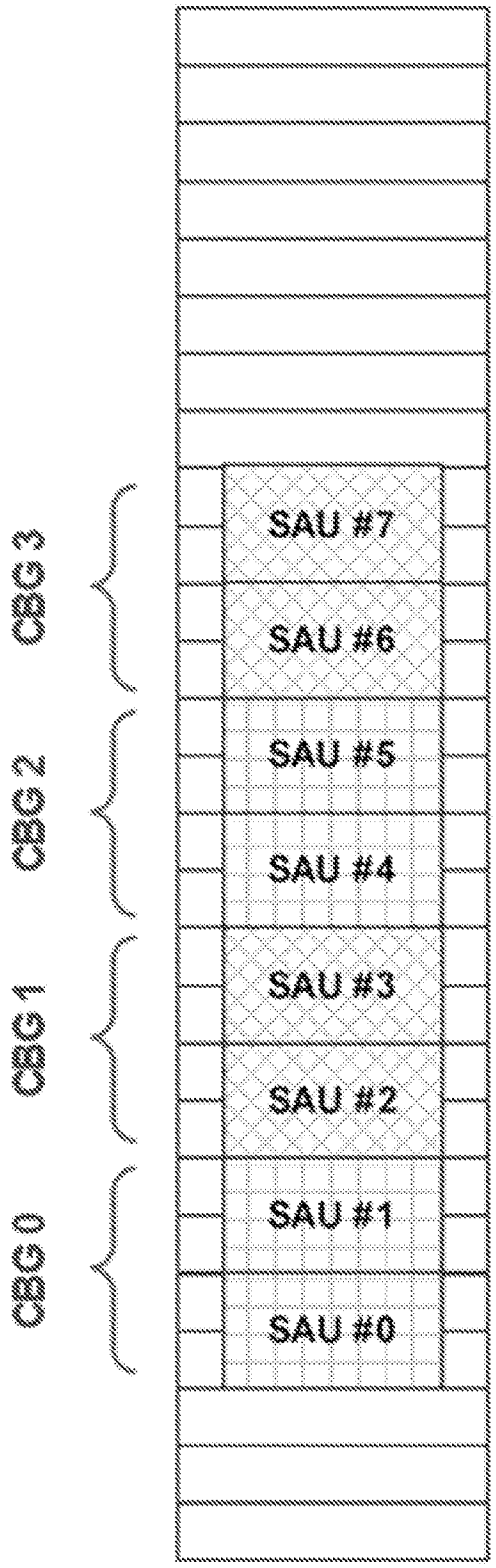


Figure 4. Illustration of a symbol alignment unit in time domain resource allocation

Figure 4

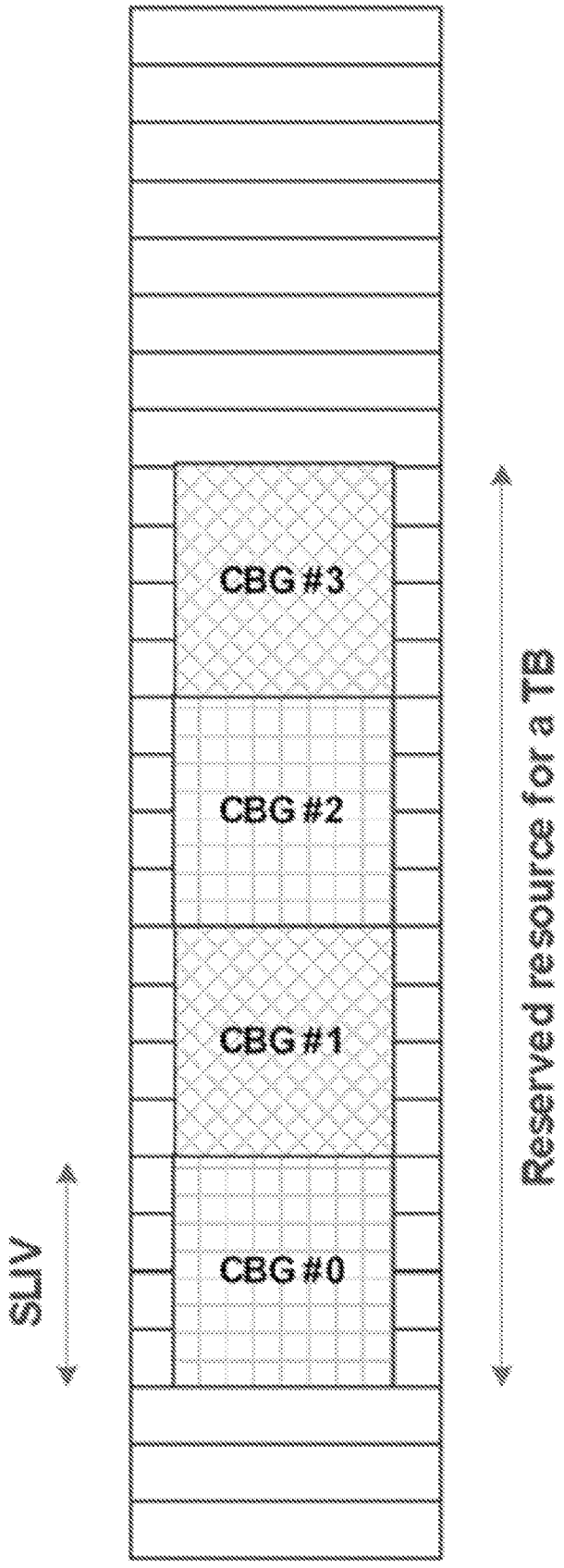


Figure 5. Illustration of single TB scheduled with multiple CBGs by a DCI

Figure 5

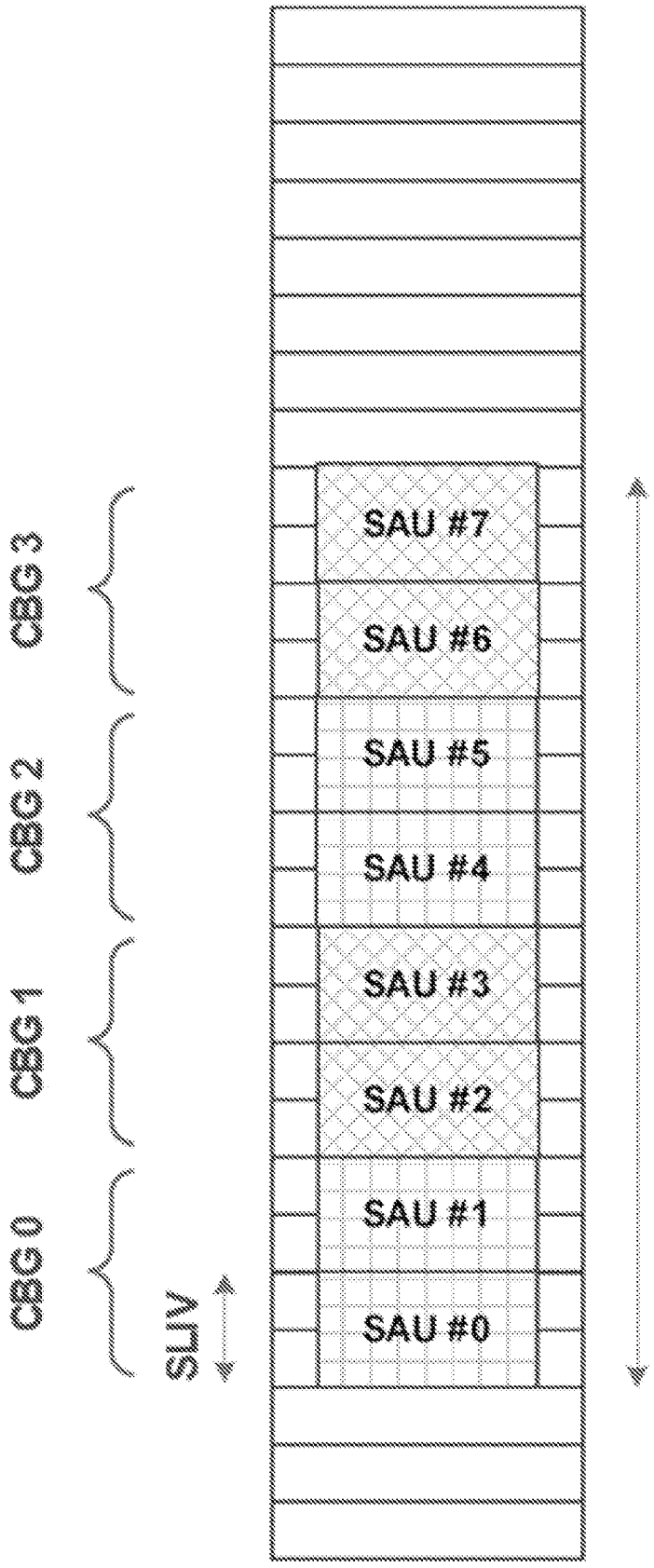


Figure 6. single TB scheduling with multiple SAUs by a DCI

Figure 6

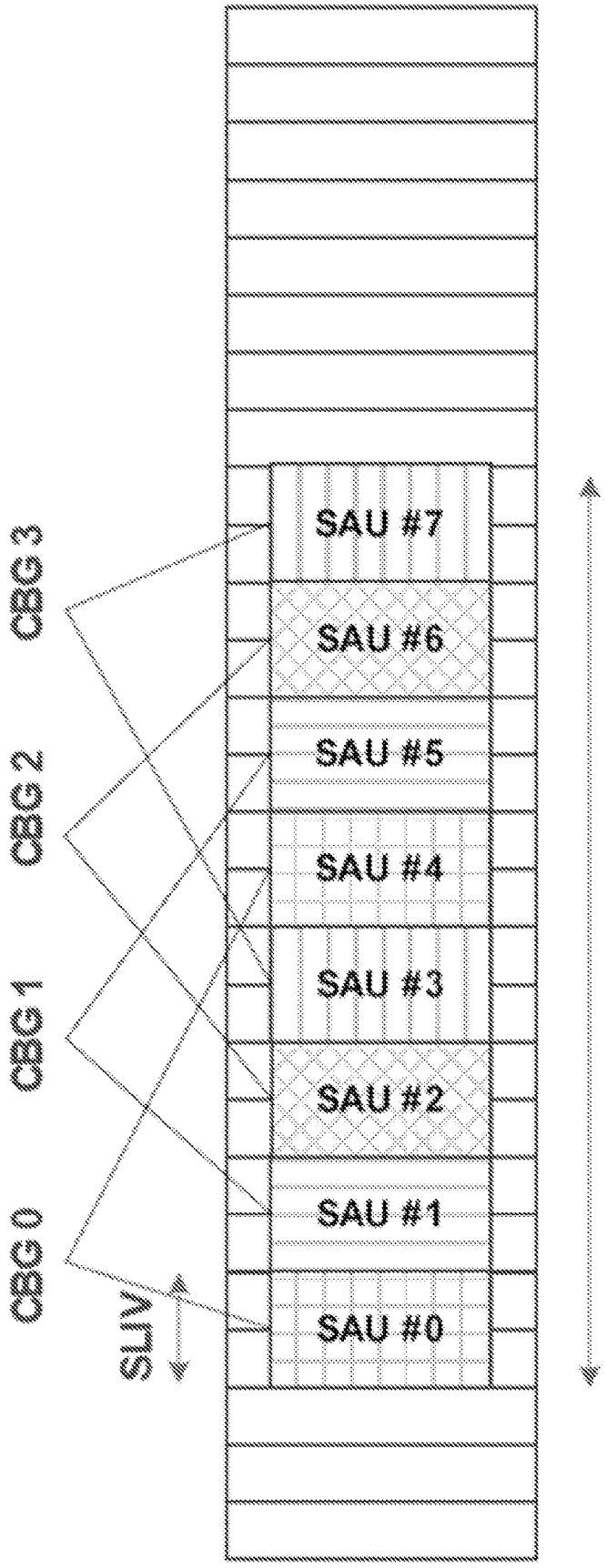


Figure 7

Figure 7. single TB scheduling with multiple SAUs by a DCI

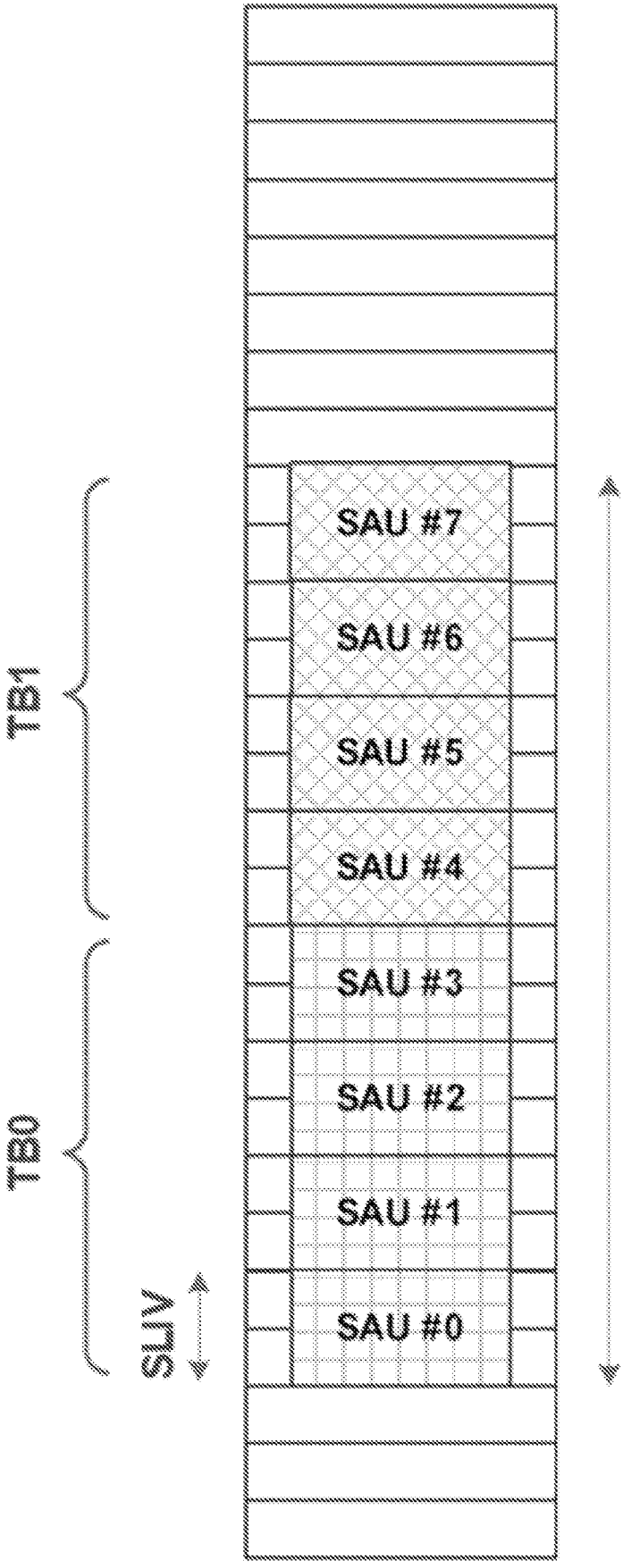


Figure 8. 2-TB scheduling with multiple SAUs by a DCI

Figure 8

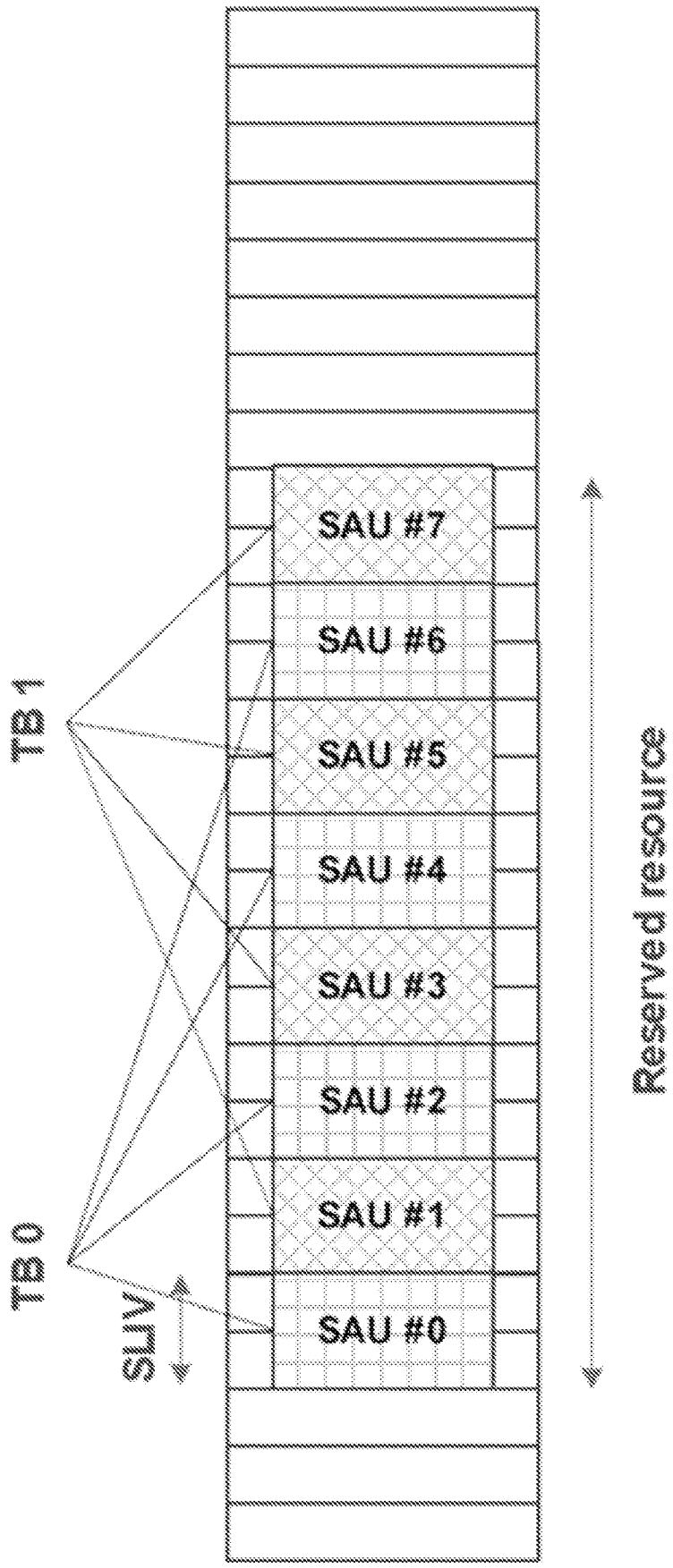


Figure 9. 2-TB scheduling with multiple SAUs by a DCI

Figure 9

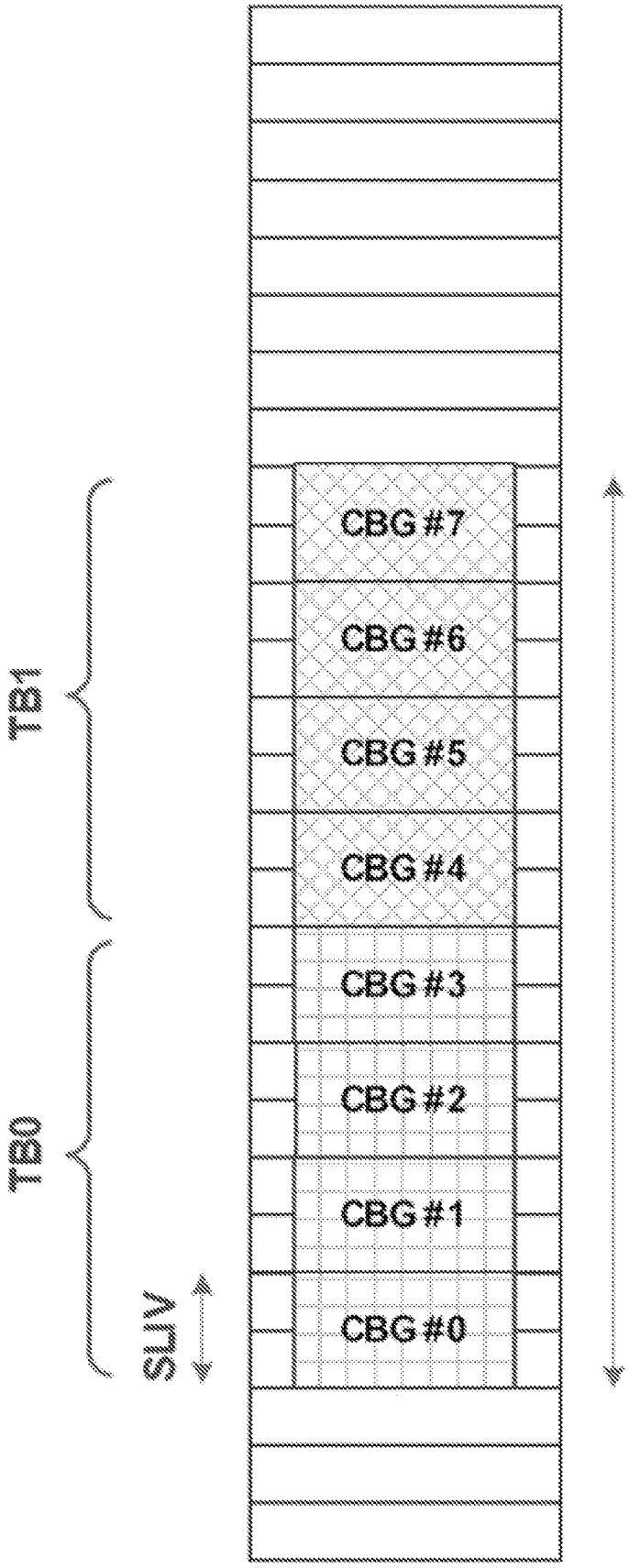


Figure 10. 2-TB scheduling with multiple CBGs by a DCI

Figure 10

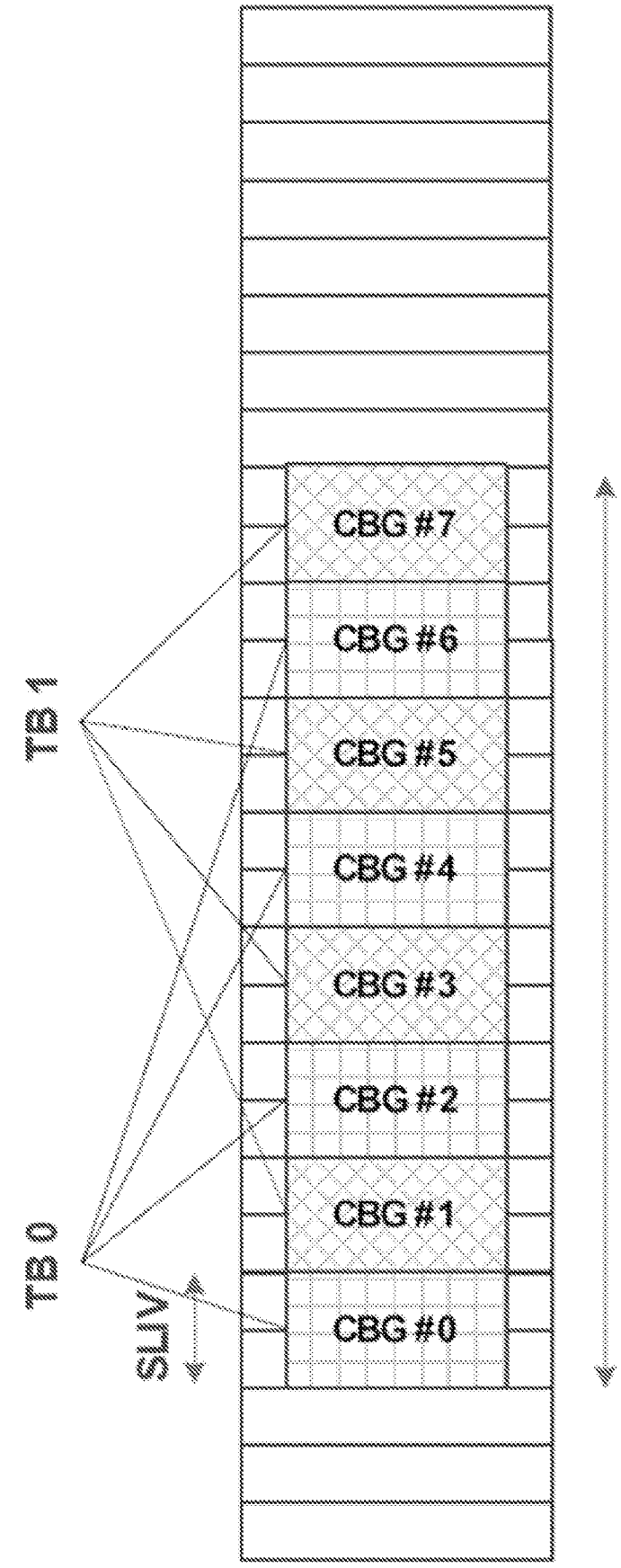


Figure 11. 2-TB scheduling with multiple CBGs by a DCI

Figure 11

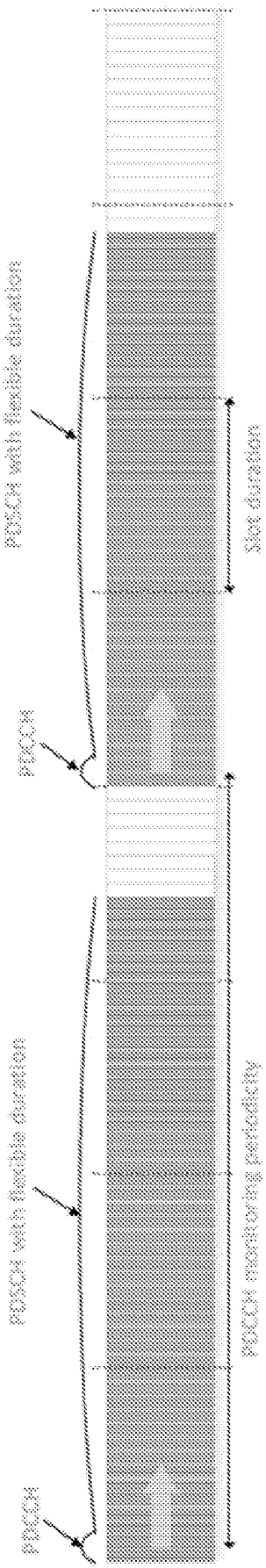


Figure 12 Illustration of PDSCH scheduling with flexible duration and pre-determined PDCCH monitoring occasions

Figure 12

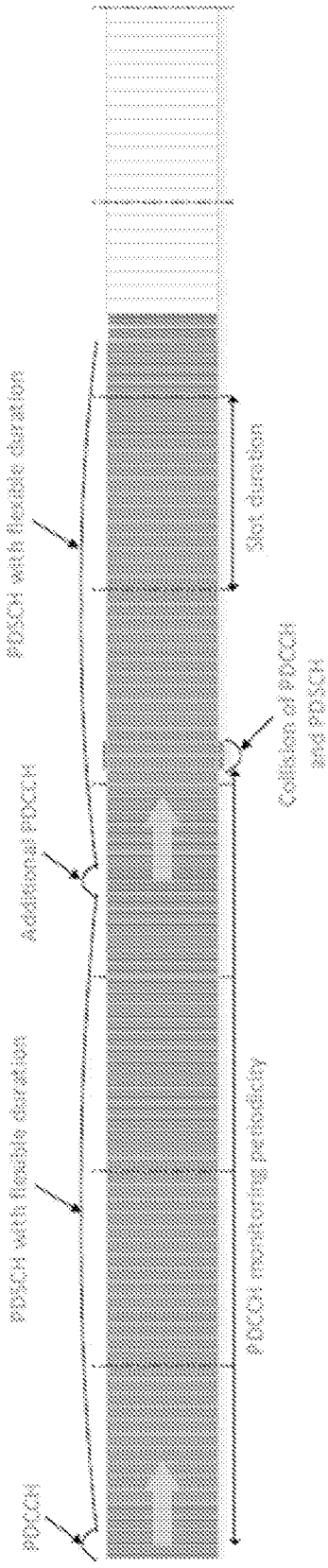


Figure 13 Illustration of PDSCH scheduling with flexible duration and new PDCCH monitoring after PDSCH

Figure 13

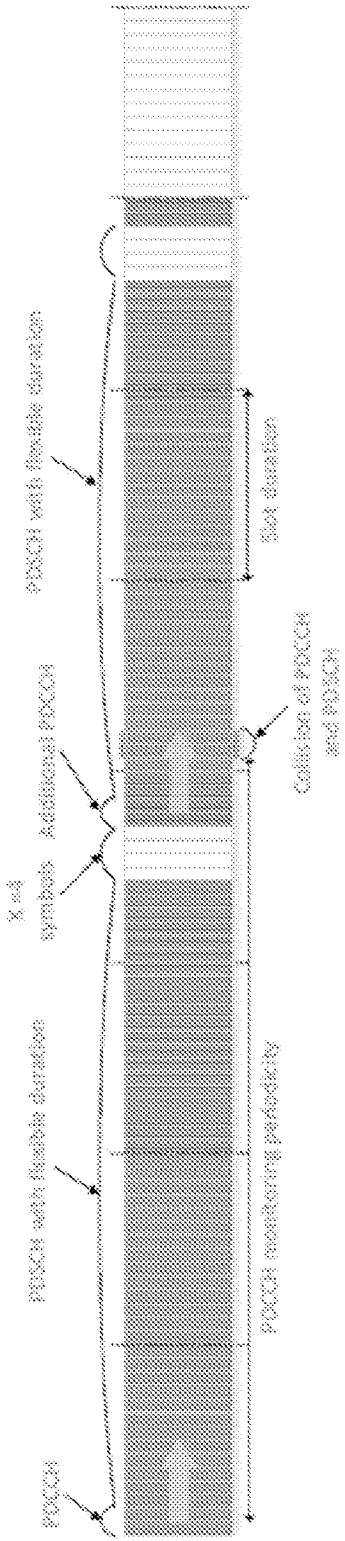
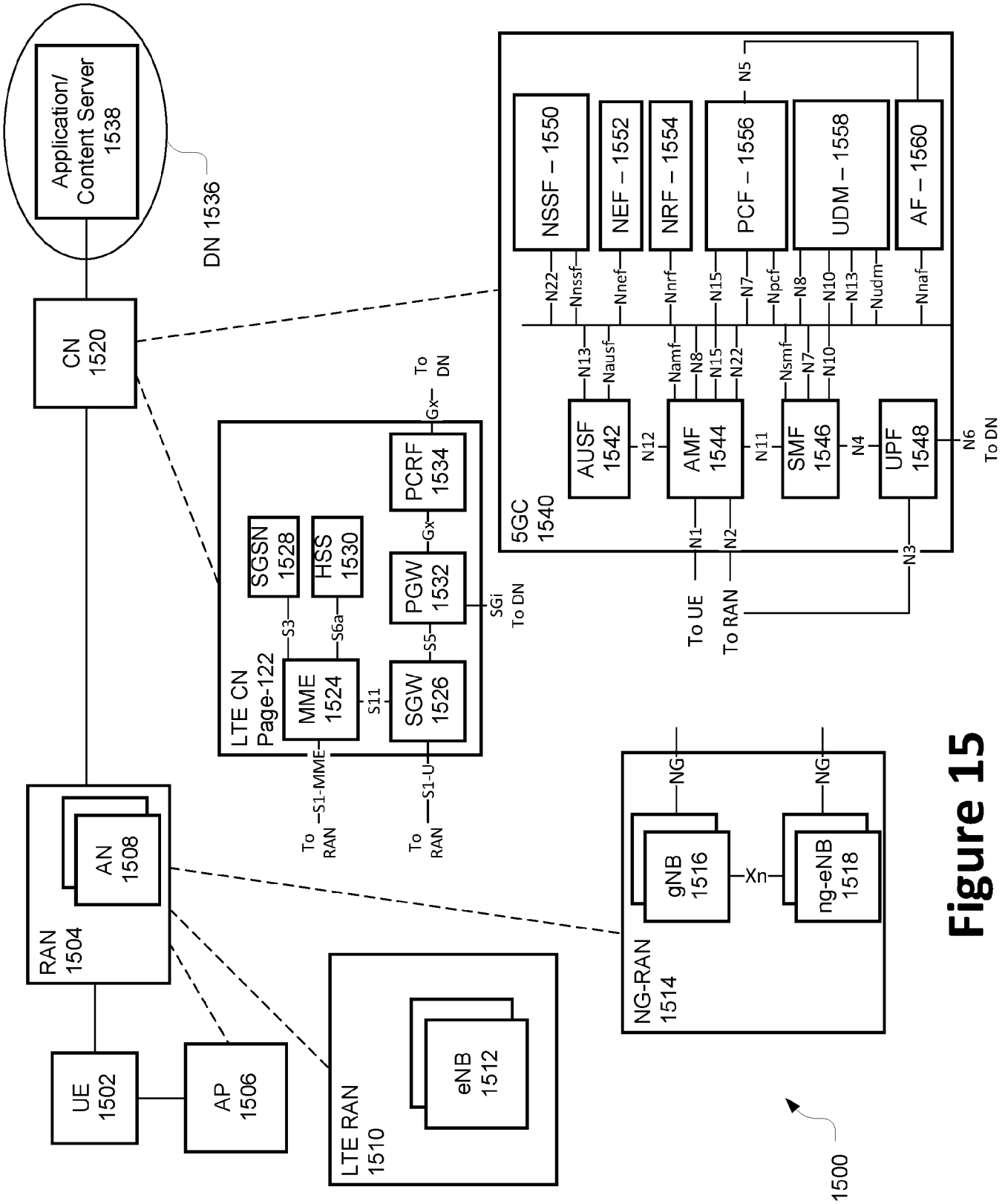


Figure 14 Illustration of PDSCH scheduling with flexible duration and new PDCCH monitoring in X symbol after PDSCH

Figure 14


Application/ Content Server 1538
DN 1536
CN 1520
5GC 1540
NSSF – 1550
NEF – 1552
NRF – 1554
PCF – 1556
UDM – 1558
AF – 1560
AUSF 1542
AMF 1544
SMF 1546
UPF 1548
N22
Nnssf
Nnef
Nnrf
N15
N7
Npcf
N8
N10
N13
Nudm
Nnaf
N13
Nausf
Namf
N8
N15
N22
Nsmf
N7
N10
N12
N11
N4
N6
To DN
N1
N2
N3
To UE
To RAN
LTE CN Page-122
MME 1524
SGW 1526
PGW 1532
PCRF 1534
SGSN 1528
HSS 1530
S3
S6a
S11
S5
Gx
SGi
To DN
To DN
S1-MME
S1-U
To RAN
To RAN
RAN 1504
AN 1508
UE 1502
AP 1506
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gNB 1516
ng-eNB 1518
Xn
NG
NG
1500

Figure 15

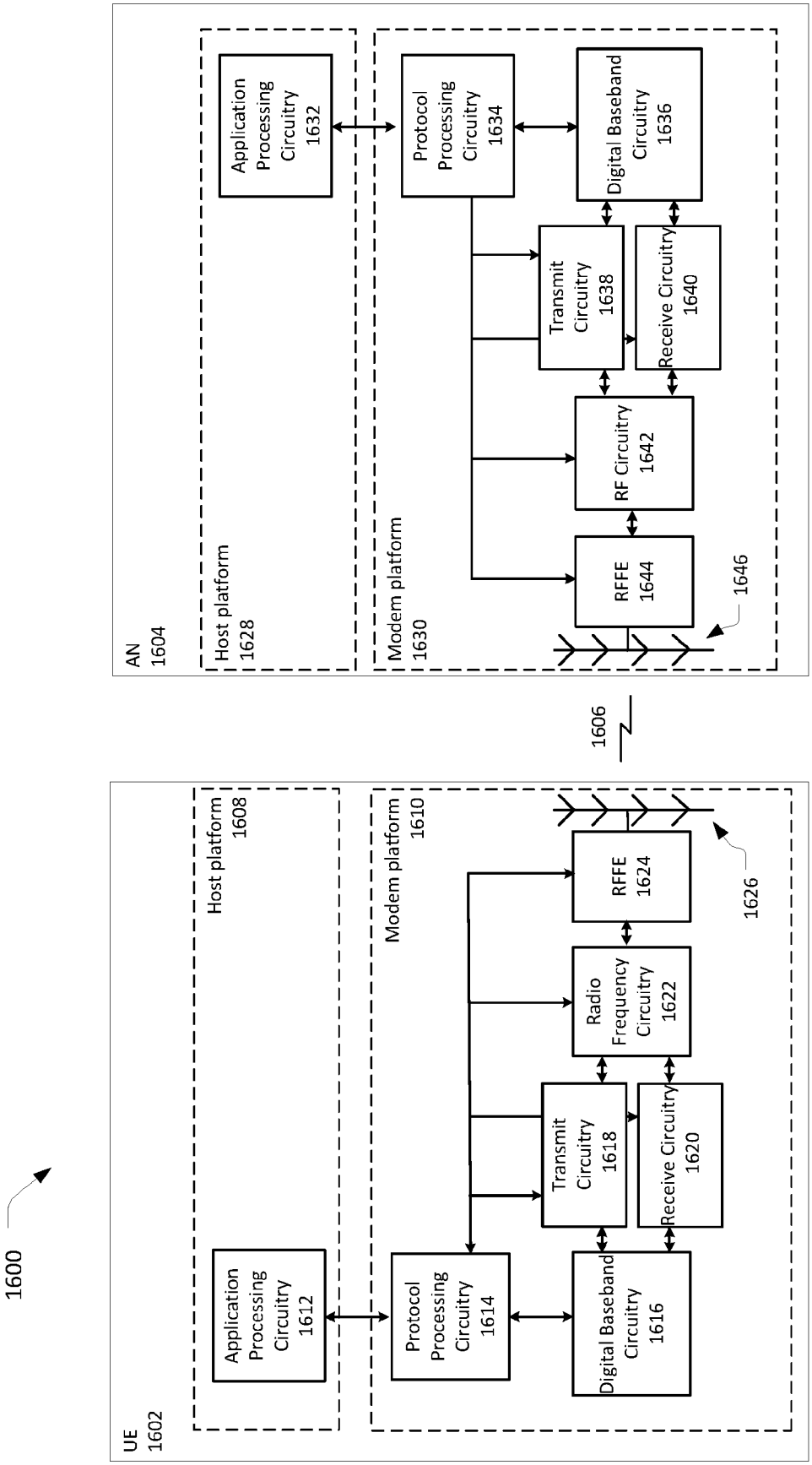
1600
UE
1602
Host platform
1608
Application Processing Circuitry
1612
Modem platform
1610
Protocol Processing Circuitry
1614
Digital Baseband Circuitry
1616
Transmit Circuitry
1618
Receive Circuitry
1620
Radio Frequency Circuitry
1622
RFFE
1624
1626
1606
AN
1604
Host platform
1628
Application Processing Circuitry
1632
Modem platform
1630
Protocol Processing Circuitry
1634
Digital Baseband Circuitry
1636
Transmit Circuitry
1638
Receive Circuitry
1640
RF Circuitry
1642
RFFE
1644
1646

Figure 16

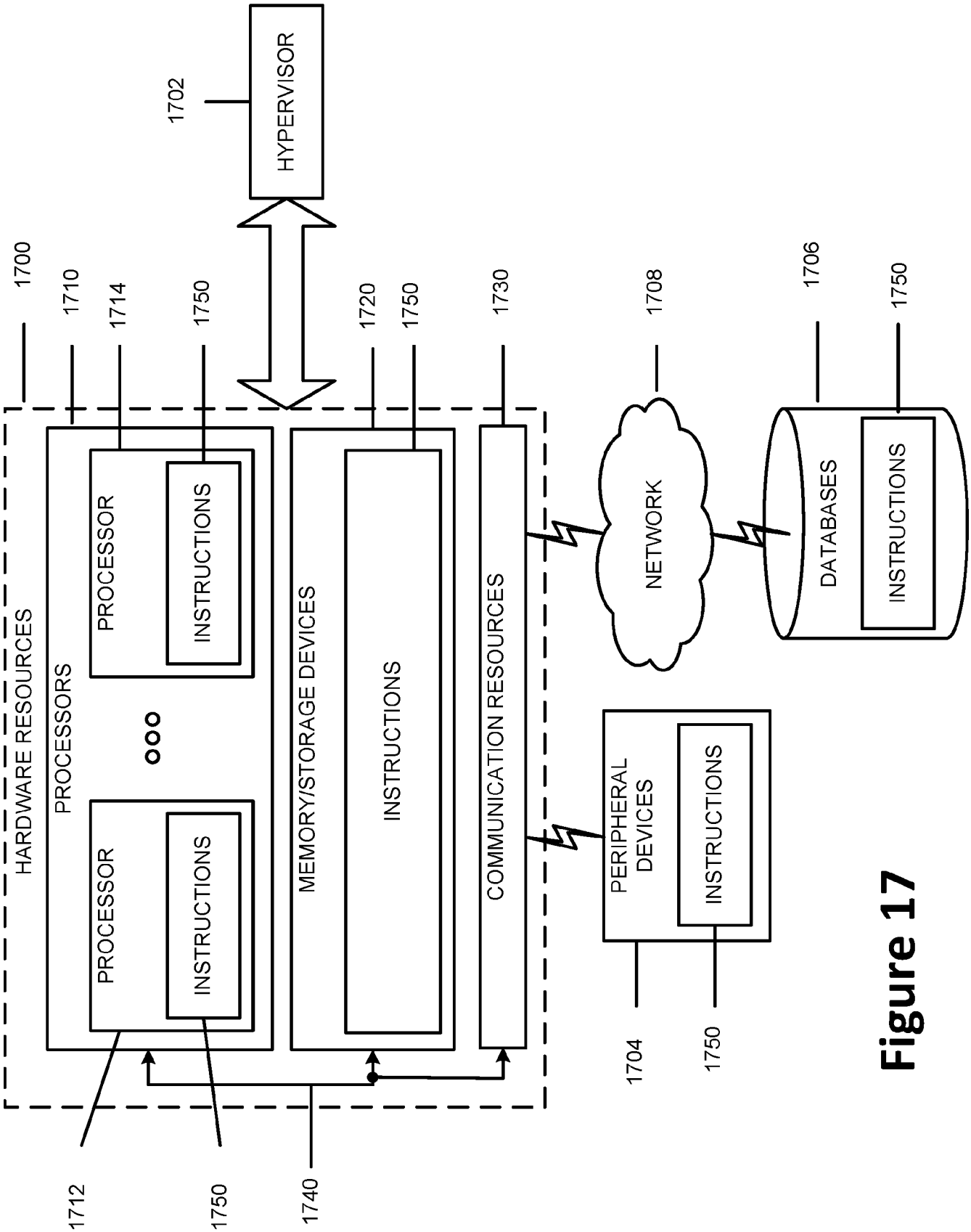
HYPERVISOR
1702
HARDWARE RESOURCES
1700
PROCESSORS
1710
PROCESSOR
1714
INSTRUCTIONS
1750
PROCESSOR
INSTRUCTIONS
1712
1750
MEMORY/STORAGE DEVICES
1720
INSTRUCTIONS
1750
1740
COMMUNICATION RESOURCES
1730
NETWORK
1708
DATABASES
1706
INSTRUCTIONS
1750
PERIPHERAL DEVICES
1704
INSTRUCTIONS
1750

Figure 17

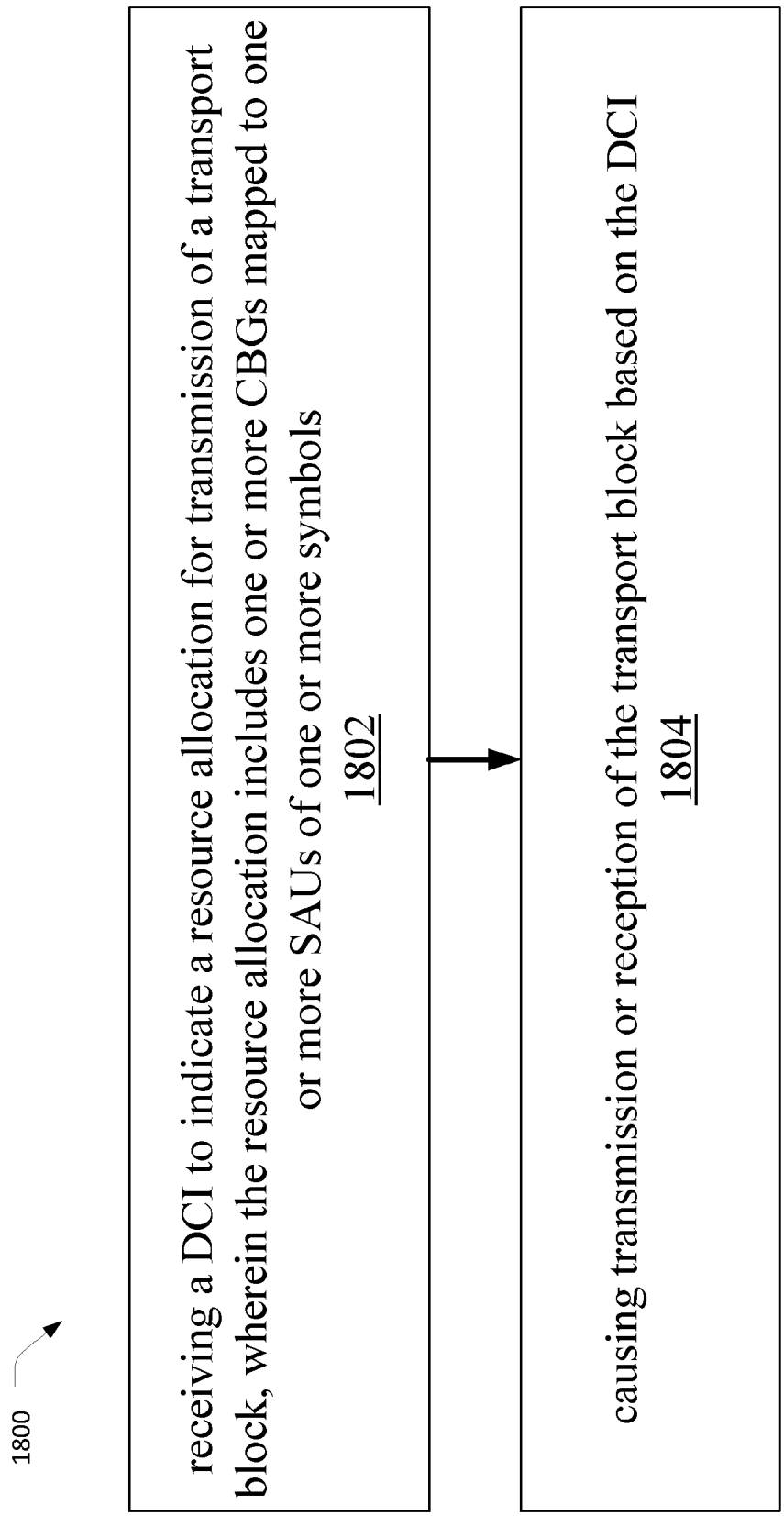
1800
receiving a DCI to indicate a resource allocation for transmission of a transport block, wherein the resource allocation includes one or more CBGs mapped to one or more SAUs of one or more symbols
1802
causing transmission or reception of the transport block based on the DCI
1804

Figure 18

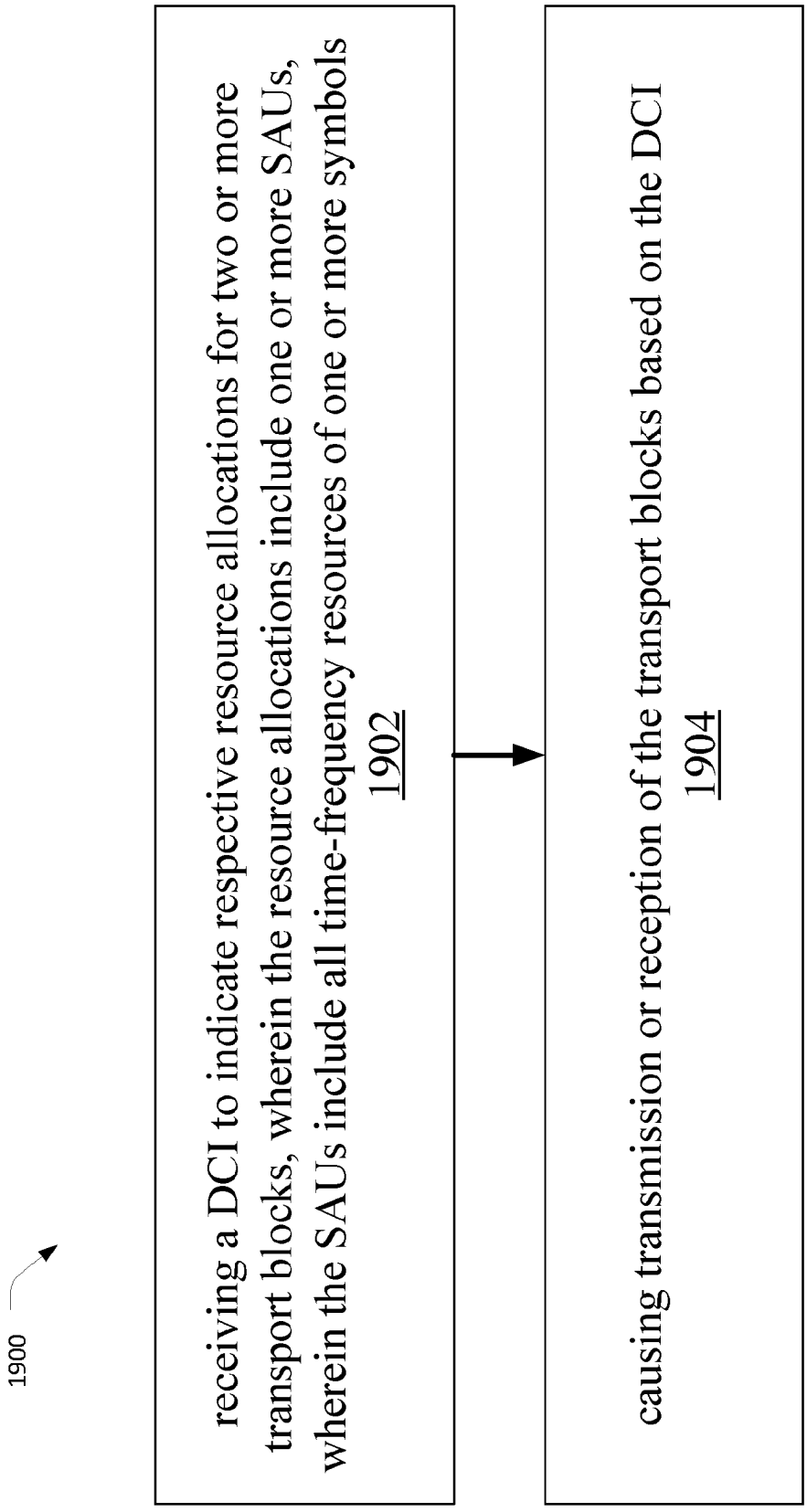
1900
receiving a DCI to indicate respective resource allocations for two or more transport blocks, wherein the resource allocations include one or more SAUs, wherein the SAUs include all time-frequency resources of one or more symbols
1902
causing transmission or reception of the transport blocks based on the DCI
1904

Figure 19

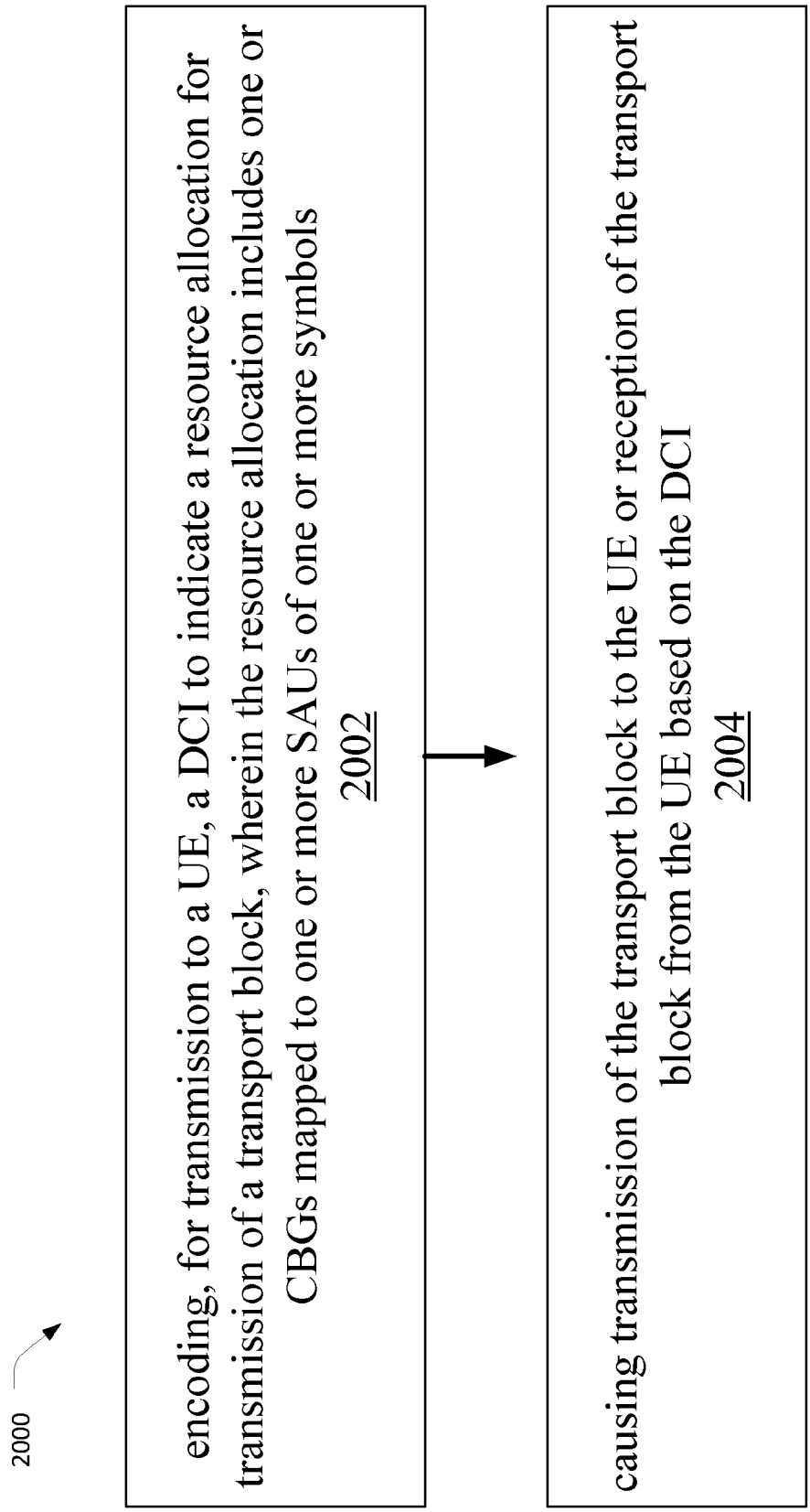
2000
encoding, for transmission to a UE, a DCI to indicate a resource allocation for transmission of a transport block, wherein the resource allocation includes one or CBGs mapped to one or more SAUs of one or more symbols
2002
causing transmission of the transport block to the UE or reception of the transport block from the UE based on the DCI
2004

Figure 20

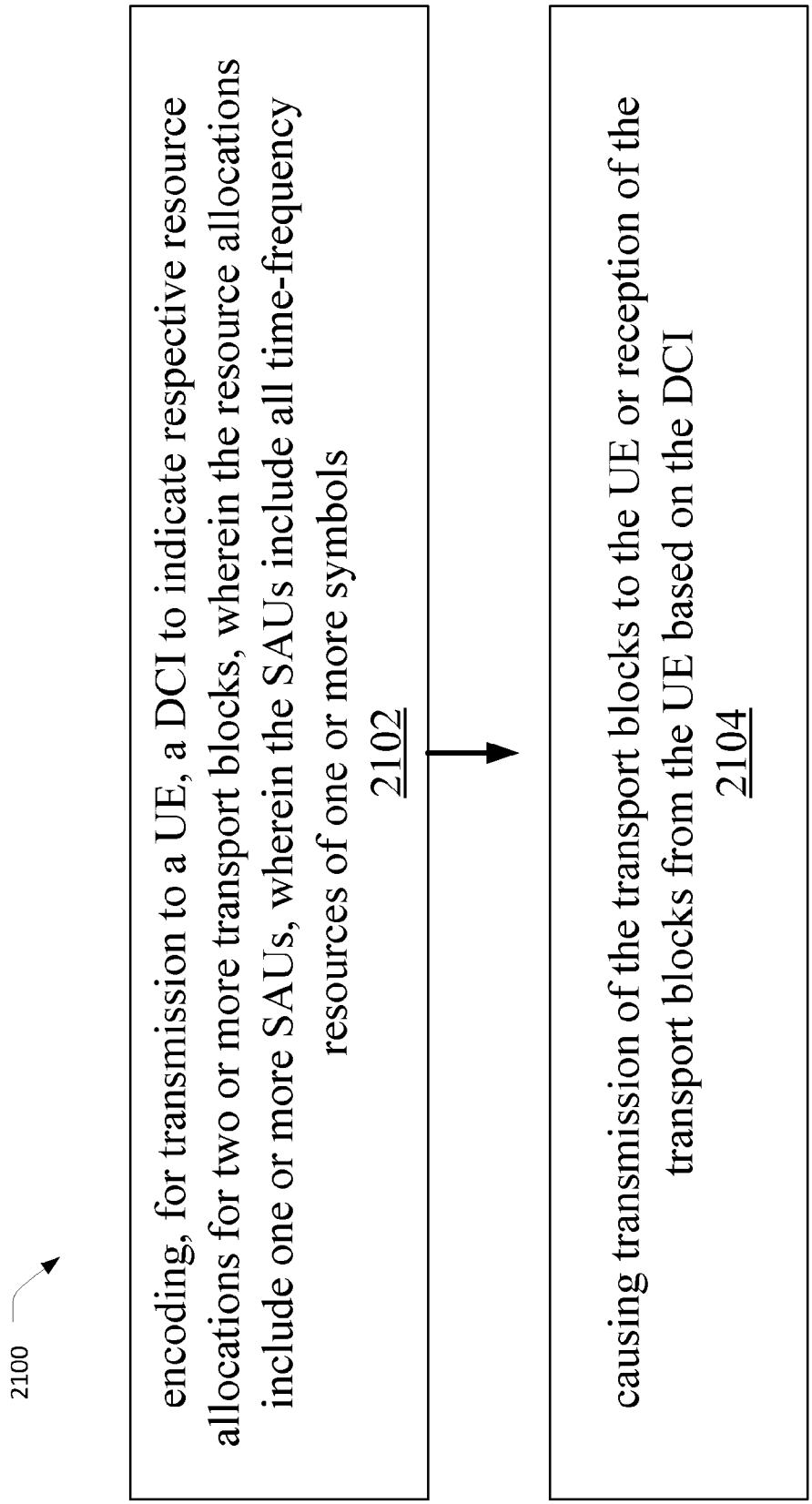
2100
encoding, for transmission to a UE, a DCI to indicate respective resource allocations for two or more transport blocks, wherein the resource allocations include one or more SAUs, wherein the SAUs include all time-frequency resources of one or more symbols
2102
causing transmission of the transport blocks to the UE or reception of the transport blocks from the UE based on the DCI
2104

Figure 21

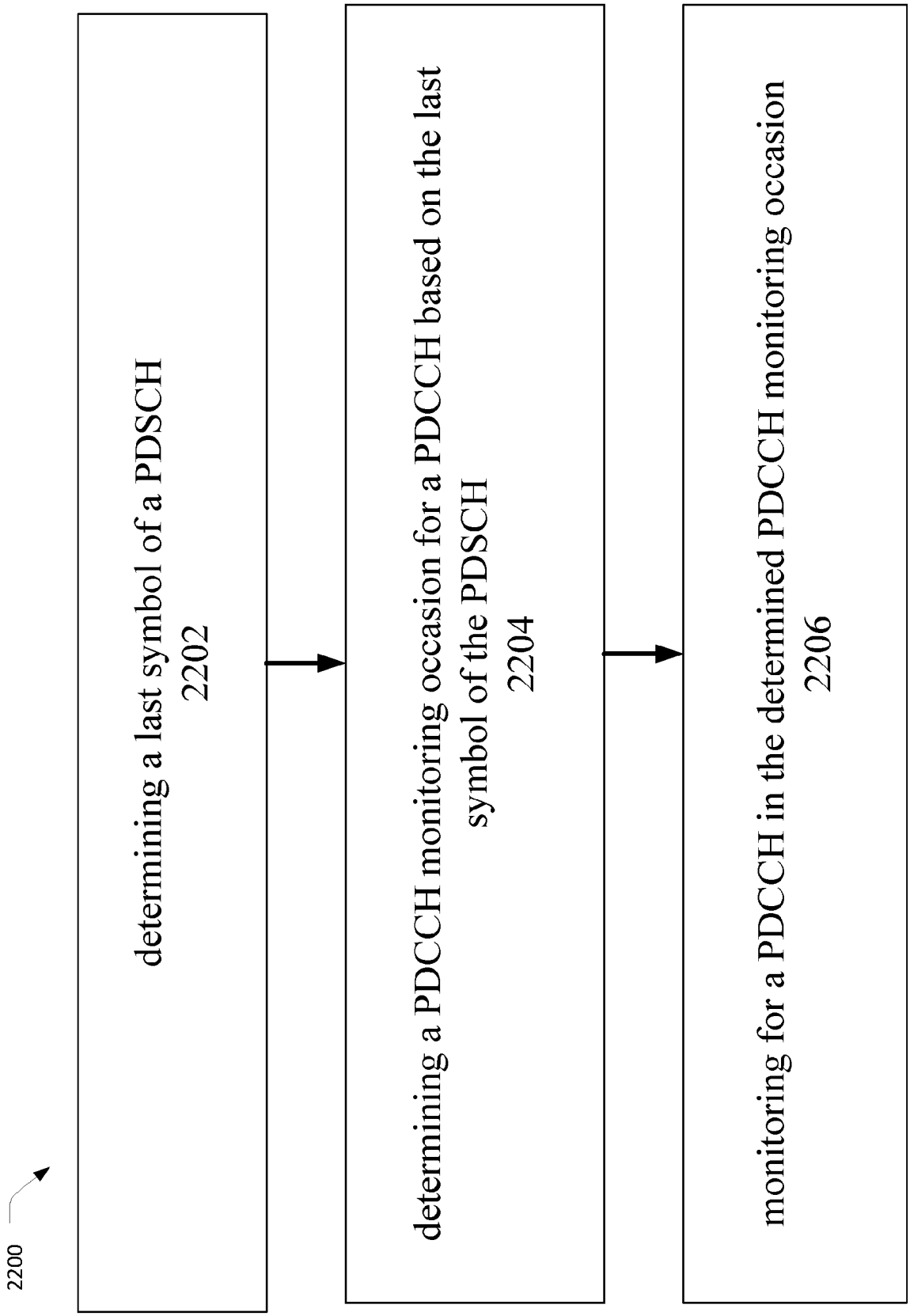
2200
determining a last symbol of a PDSCH
2202
determining a PDCCH monitoring occasion for a PDCCH based on the last symbol of the PDSCH
2204
monitoring for a PDCCH in the determined PDCCH monitoring occasion
2206

Figure 22

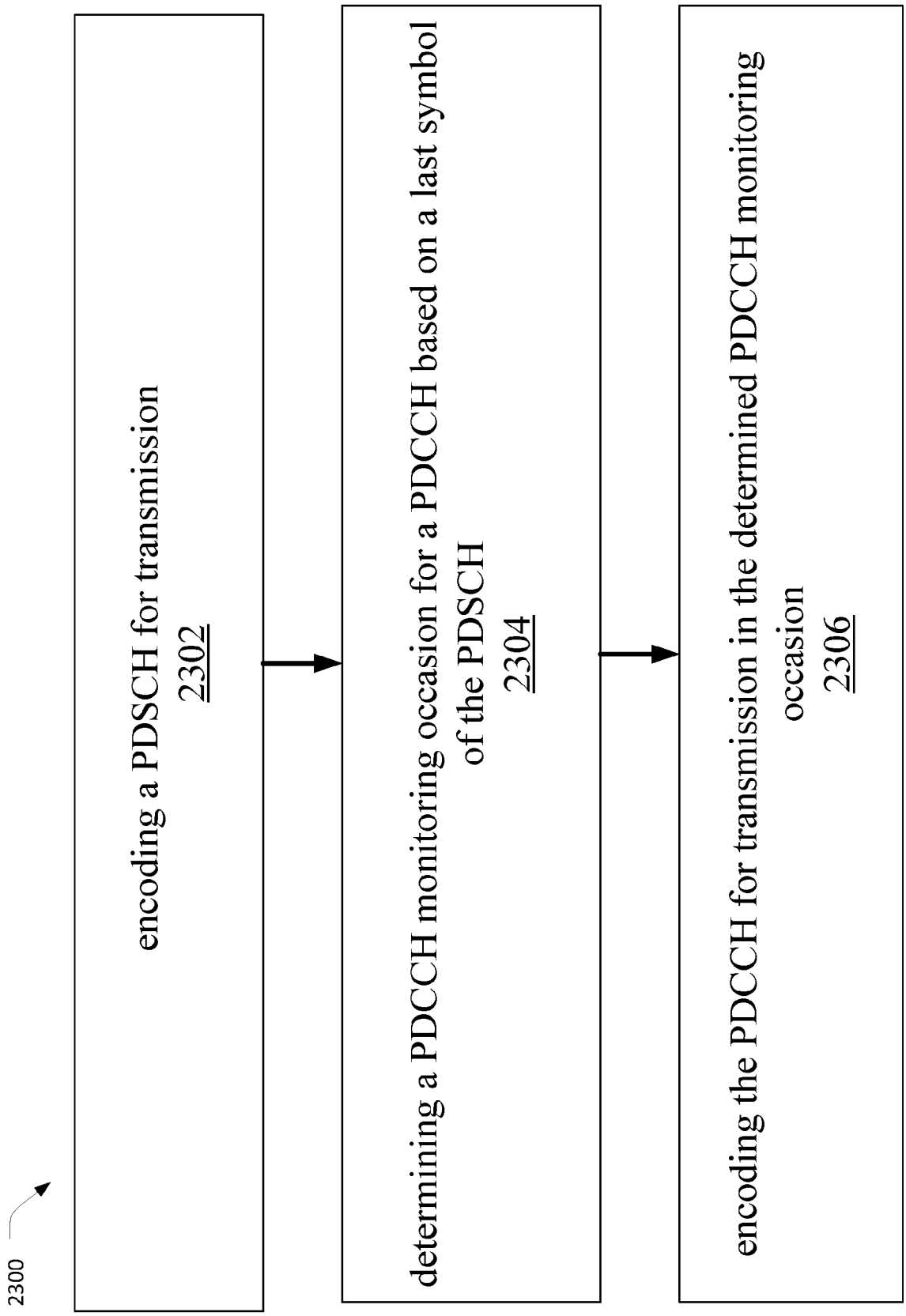
2300
encoding a PDSCH for transmission
2302
determining a PDCCH monitoring occasion for a PDCCH based on a last symbol of the PDSCH
2304
encoding the PDCCH for transmission in the determined PDCCH monitoring occasion
2306

Figure 23

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2021/039072

A. CLASSIFICATION OF SUBJECT MATTER

H04W 72/12(2009.01)i; **H04W 72/04**(2009.01)i; **H04L 5/00**(2006.01)i

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)

H04W 72/12(2009.01); H04L 1/00(2006.01); H04L 27/26(2006.01); H04W 52/02(2009.01); H04W 72/04(2009.01)

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

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: PDSCH last symbol, PDCCH monitoring occasion

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2015-190883 A1 (LG ELECTRONICS INC.) 17 December 2015 (2015-12-17) paragraphs [0088]-[0092]; claims 1, 7; and figure 6	1-14
A	US 2017-0332379 A1 (CHINA ACADEMY OF TELECOMMUNICATIONS TECHNOLOGY) 16 November 2017 (2017-11-16) paragraphs [0109]-[0127]; and figure 3	1-14
A	US 2020-0037245 A1 (ASUSTEK COMPUTER INC.) 30 January 2020 (2020-01-30) paragraphs [0337]-[0369]; and figures 15-18	1-14
A	US 2020-0059912 A1 (VIVO MOBILE COMMUNICATION CO., LTD.) 20 February 2020 (2020-02-20) paragraphs [0104]-[0131]; and figure 9	1-14
A	`3GPP; TSG RAN; NR; Physical layer procedures for control (Release 16)', 3GPP TS 38.213 V16.1.0, 03 April 2020 section 10.1	1-14

☐ 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
"D" document cited by the applicant in the international application
"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	Date of mailing of the international search report
16 November 2021	**17 November 2021**

Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office **189 Cheongsa-ro, Seo-gu, Daejeon** **35208, Republic of Korea**	**YANG, JEONG ROK**
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2021/039072

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

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

Group I: Claims 1-14 directed to a UE and a gNB for scheduling a PDSCH with a flexible duration and a new PDCCH monitoring after a last symbol of the PDSCH.

Group II: Claims 15-23 directed to a UE for receiving a DCI indicating a resource allocation for transport blocks, wherein the resource allocation includes symbol alignment units.

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

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

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

4. ☑ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.: **1-14**

Remark on Protest

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

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

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/US2021/039072

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