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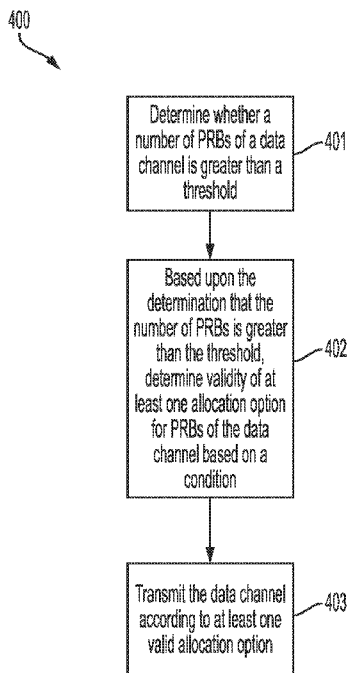


FIG. 4

(57) Abstract: Systems, methods, apparatuses, and computer program products for determining valid allocation sizes for DFT-s-OFDM. One method may include determining whether a number of PRBs of a data channel is greater than a threshold; based upon the determination that the number of PRBs is greater than the threshold, determining validity of at least one allocation option for PRBs of the data channel; and transmitting the data channel according to at least one valid allocation option. The at least one allocation option defines a bandwidth of the data channel in terms of the number of PRBs.

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DISCRETE FOURIER TRANSFORM-SPREAD-ORTHOGONAL FREQUENCY-DIVISION MODULATION ALLOCATION FOR WIDE BANDWIDTH OPERATION

5 **RELATED APPLICATION**

This application is related to and claims the priority of Finland national Patent Application No. 20236385, filed December 18, 2023, the entirety of which is hereby incorporated herein by reference.

10 **TECHNICAL FIELD**

[0001] Some example embodiments may generally relate to mobile or wireless telecommunication systems, such as 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE), 5th generation (5G) radio access technology (RAT), new radio (NR) access technology, 6th generation (6G), single-carrier frequency-division multiple access (SC-FDMA),
15 frequency-domain spectral shaping (FDSS), filtered DFT-s-OFDM, and/or other communications systems. For example, certain example embodiments may relate to systems and/or methods for determining valid allocation sizes for discrete Fourier transform (DFT)-spread (s)-orthogonal frequency-division modulation (OFDM).

20 **BACKGROUND**

[0002] Examples of mobile or wireless telecommunication systems may include the Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access Network (UTRAN), LTE Evolved UTRAN (E-UTRAN), LTE-Advanced (LTE-A), LTE-A Pro, NR access technology, 5G, 6G, and/or MulteFire Alliance. 5G wireless systems refer to the next generation
25 (NG) of radio systems and network architecture. Frequency bands for 5G are separated into two different frequency ranges (FRs): FR1 that includes sub-6 GHz frequency bands, and FR2 that includes frequency bands from 24.25 GHz to 71 GHz. A 5G system is typically built on a 5G NR, but a 5G (or NG) network may also be built on E-UTRA radio. It is expected that NR can support service categories such as enhanced mobile broadband (eMBB), ultra-reliable low-
30 latency-communication (URLLC), and massive machine-type communication (mMTC). NR is expected to deliver extreme broadband, ultra-robust, low-latency connectivity, and massive

networking to support the Internet of Things (IoT). The next generation radio access network (NG-RAN) represents the radio access network (RAN) for 5G, which may provide radio access for NR, LTE, and LTE-A. It is noted that the nodes in 5G providing radio access functionality to a user equipment (*e.g.*, similar to the Node B in UTRAN or the Evolved Node B (eNB) in
5 LTE) may be referred to as next-generation Node B (gNB) when built on NR radio, and may be referred to as next-generation eNB (NG-eNB) when built on E-UTRA radio. Technology studies for 6G in 3GPP are expected to start in Release 20, and normative 6G standardization may be undertaken in Release 21. A 6G system may exploit frequency bands between FR1 and FR2 (*i.e.*, 7.125GHz-24.25 GHz), which may be termed as FR3.

SUMMARY

[0003] In accordance with some example embodiments, a method may include determining, by a user equipment, whether a number of PRBs of a data channel is greater than a threshold. The method may further include, based upon the determination that the number of PRBs is
15 greater than the threshold, determining, by the user equipment, validity of at least one allocation option for PRBs of the data channel based on a condition. The at least one allocation option defines a bandwidth of the data channel in terms of the number of PRBs. The method may further include transmitting, by the user equipment, the data channel according to at least one valid allocation option.

[0004] In accordance with certain example embodiments, an apparatus may include means for determining whether a number of PRBs of a data channel is greater than a threshold. The apparatus may further include means for, based upon the determination that the number of PRBs is greater than the threshold, determining validity of at least one allocation option for PRBs of the data channel based on a condition. The at least one allocation option defines a
25 bandwidth of the data channel in terms of the number of PRBs. The apparatus may further include means for transmitting the data channel according to at least one valid allocation option.

[0005] In accordance with various example embodiments, a non-transitory computer readable medium may include program instructions that, when executed by an apparatus, cause the apparatus to perform at least a method. The method may include determining whether a number
30 of PRBs of a data channel is greater than a threshold. The method may further include, based upon the determination that the number of PRBs is greater than the threshold, determining

validity of at least one allocation option for PRBs of the data channel based on a condition. The at least one allocation option defines a bandwidth of the data channel in terms of the number of PRBs. The method may further include transmitting the data channel according to at least one valid allocation option.

5 [0006] In accordance with some example embodiments, a computer program product may perform a method. The method may include determining whether a number of PRBs of a data channel is greater than a threshold. The method may further include, based upon the determination that the number of PRBs is greater than the threshold, determining validity of at least one allocation option for PRBs of the data channel based on a condition. The at least one allocation option defines a bandwidth of the data channel in terms of the number of PRBs. The method may further include transmitting the data channel according to at least one valid allocation option.

[0007] In accordance with certain example embodiments, an apparatus may include at least one processor and at least one memory storing instructions that, when executed by the at least one processor, cause the apparatus at least to determine whether a number of PRBs of a data channel is greater than a threshold. The at least one memory and instructions, when executed by the at least one processor, may further cause the apparatus at least to, based upon the determination that the number of PRBs is greater than the threshold, determine validity of at least one allocation option for PRBs of the data channel based on a condition. The at least one allocation option defines a bandwidth of the data channel in terms of the number of PRBs. The at least one memory and instructions, when executed by the at least one processor, may further cause the apparatus at least to transmit the data channel according to at least one valid allocation option.

[0008] In accordance with various example embodiments, an apparatus may include determining circuitry configured to perform determining whether a number of PRBs of a data channel is greater than a threshold. The apparatus may further include determining circuitry configured to perform, based upon the determination that the number of PRBs is greater than the threshold, determining validity of at least one allocation option for PRBs of the data channel based on a condition. The at least one allocation option defines a bandwidth of the data channel in terms of the number of PRBs. The apparatus may further include transmitting circuitry

configured to perform transmitting the data channel according to at least one valid allocation option.

BRIEF DESCRIPTION OF THE DRAWINGS

- 5 [0009] For a proper understanding of example embodiments, reference should be made to the accompanying drawings, wherein:
- [0010] FIG. 1 illustrates an example of DFT-s-OFDM TX processing;
- [0011] FIG. 2 illustrates an example of DFT-s-OFDM RX processing;
- [0012] FIG. 3 illustrates an example of a flow diagram of a method according to certain
10 example embodiments;
- [0013] FIG. 4 illustrates an example of a flow diagram of a method according to certain example embodiments;
- [0014] FIG. 5 illustrates an example of some network devices according to some example embodiments; and
- 15 [0015] FIG. 6 illustrates an example of a 5G network and system architecture according to certain example embodiments.

DETAILED DESCRIPTION

- [0016] It will be readily understood that the components of certain example embodiments,
20 as generally described and illustrated in the figures herein, may be arranged and designed in a wide variety of different configurations. Thus, the following detailed description of some example embodiments of systems, methods, apparatuses, and computer program products for determining valid allocation sizes for DFT-s-OFDM is not intended to limit the scope of certain example embodiments, but is instead representative of selected example
25 embodiments.
- [0017] In fifth-generation new radio (5G NR), OFDM may be used in downlink (DL) while both OFDM and DFT-s-OFDM are supported in uplink (UL). Among these two alternatives, DFT-s-OFDM may provide better power amplifier (PA) efficiency, larger PA output powers, and be more robust under phase noise. Therefore, DFT-s-OFDM may be beneficial in DL in
30 6G developments, especially for mmWave and/or sub-THz frequencies. The same

waveforms (*e.g.*, cyclic prefix (CP)-OFDM and DFT-s-OFDM) may also be applied in 6G UL.

[0018] DFT-s-OFDM waveform may be generated by using DFT and inverse fast Fourier transform (IFFT) of sizes L and N , respectively. The feasible IFFT sizes in 5G may be restricted, being either power-of-two ($N = 2^a$) or three times the power of two ($N = 3 \times 2^a$). Valid allocation size in terms of number of physical resource blocks (PRBs) for DFT-s-OFDM may be calculated using Equation (1):

$$L_{\text{PRB}} = 2^a \times 3^b \times 5^c \quad \text{Equation (1),}$$

wherein a , b , and c are non-negative integers. This restricted allocation size set may be defined to provide sufficient flexibility in choosing the transmission bandwidth (TBW). Consequently, this allocation size may also define the DFT size as $L = 12 \times L_{\text{PRB}}$, where L can be deemed as allocation size in terms of number of resource elements (REs) or number of subcarriers when one PRB comprises 12 REs/subcarriers, and, thereby, efficient implementations for the transforms may be used in terms of prime-factor FFT algorithms.

Supported allocation sizes for DFT-s-OFDM in 5G are discussed in more detail below.

[0019] The maximum channel bandwidth (CBW) supported by the 5G NR in FR1 is 100 MHz. IFFT of size 4096 may be used to generate OFDM and DFT-s-OFDM waveforms for 100 MHz CBW with 30 kHz subcarrier spacing (SCS). The maximum number of PRBs in 5G NR is 275, which corresponds to 3300 subcarriers.

[0020] In 6G developments, wider CBWs may be defined for frequency bands below 15GHz, but the required IFFT sizes may increase. For example, 400 MHz CBW may require 16384 IFFT size for 30 kHz SCS, and 8192 IFFT size for 60 kHz SCS. Consequently, the needed DFT sizes in DFT-s-OFDM waveform generation and receiver processing may need to be increased as well. 500 MHz CBW may be utilized, such as 30 kHz SCS (*i.e.*, 16384 IFFT (4x 4096 IFFT or 2x 8192 IFFT), 20480 IFFT (5x 4096 IFFT or 2x 8192 IFFT + 2x 2048 IFFT)), and/or 60 kHz SCS (8192 IFFT (2x 4096 IFFT) or 10240 IFFT (5x 2048 IFFT or 8192 IFFT+2048 IFFT)).

[0021] 30 kHz SCS may be preferable for dynamic spectrum sharing with 5G (in FR1). In order to maximize the similarity between FR1 and FR3, 30 kHz SCS may be preferred for FR3. One concern with 30kHz is UE velocity that may trigger 60kHz usage for upper FR3,

as well as similarities of 60kHz for lower FR3. It is noted that any of these example scenarios may involve 8192 or 16384 IFFT.

[0022] As shown in FIG. 1, DFT-s-OFDM waveform may be generated by taking the DFT (or FFT) of size L from the time-domain symbols. DFT size L may be equivalent to allocation size in number of subcarriers in 5G-NR and LTE. The resulting frequency-domain representations may be mapped into N input bins of the IFFT (*e.g.*, such that the remaining $N - L$ bins are zeros), and taking the IFFT of size N . CP may be inserted into each of the multicarrier symbols (*e.g.*, size of each multicarrier symbol may be $N + N_{CP}$, where N_{CP} is the CP length), and concatenating the multicarrier symbols. The resulting waveform may not satisfy spectral emission mask (SEM) requirements and, therefore, the waveform may be filtered for improved spectral localization. Additional filtering may improve the spectral localization of the waveform.

[0023] FIG. 2 depicts DFT-s-OFDM receiver (Rx) processing. A corresponding DFT-s-OFDM receiver processing may be carried out by converting the incoming time-domain waveform into blocks of length $N + N_{CP}$. Here, N is the FFT size, and N_{CP} is the CP length. The CP may be removed from these blocks; the block length after the CP removal may be N . The FFT of size N may be taken, and L frequency-domain bins may be selected out of the resulting N frequency-domain bins. The inverse discrete Fourier transform (IDFT) or IFFT of size L may then be taken.

[0024] As explained above, 5G may support up to 100MHz, corresponding to a maximum of 270 PRBs for DFT-s-OFDM. Possible frequency-domain resource allocation (FDRA) sizes for DFT-s-OFDM may be restricted such that $L_{PRB} = 2^a \times 3^b \times 5^c$, which may support some flexibility in choosing the TBW and to guarantee efficient implementations. In this way, for DFT-s-OFDM, only 53 allocation sizes may be configured from 273 possible sizes, as shown Table 1 below (corresponding to ~19% of all possible sizes). The corresponding needed DFT-sizes may be defined as $12 * L_{PRB}$.

1	2	3	4	5	6	8	9	10	12	15	16	18
20	24	25	27	30	32	36	40	45	48	50	54	60
64	72	75	80	81	90	96	100	108	120	125	128	135
144	150	160	162	180	192	200	216	225	240	243	250	256
270												

Table 1

[0025] 3GPP may define the maximum TBW for each CBW. In general, RAN4 may support TBWs from 1 to 273 PRBs, with 275 PRBs being the upper limit for RAN1 specs. For example, in a 20 MHz channel with 15 kHz SCS, the maximum TBW may be $L_{\text{PRB}} = 106$ PRBs or $L = 12 \times 106 = 1272$ subcarriers. Table 1 above shows all the feasible PRB sizes

5 being realizable in format of Equation (1) above (*i.e.*, $L_{\text{PRB}} = 2^a \times 3^b \times 5^c$). Here, only 53 sizes from 273 possible size may be available (corresponding to ~19% of all possible sizes).

[0026] Table 2 below provides TBW configuration L_{PRB} for CP-OFDM FR1. For each configuration, the number in parenthesis show the maximum supported FDRA size based on Equation (1) (*i.e.*, for DFT-s-OFDM) if it is different from the original TBW configuration.

SCS (kHz)	5 MHz	10 MHz	15 MHz	20 MHz	25 MHz	30 MHz	35 MHz	40 MHz	45 MHz	50 MHz	60 MHz	70 MHz	80 MHz	90 MHz	100 MHz
	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}
15	25	52 (50)	79 (75)	106 (100)	133 (128)	160	188 (180)	216	242 (240)	270	N/A	N/A	N/A	N/A	N/A
30	11 (10)	24	38 (36)	51 (50)	65 (64)	78 (75)	92 (90)	106 (100)	119 (108)	133 (128)	162 (160)	189 (180)	217 (216)	245 (240)	273 (270)
60	N/A	11 (10)	18	24	31 (30)	38 (36)	44 (40)	51 (50)	58 (54)	65 (64)	79 (75)	93 (90)	107 (100)	121 (120)	135

Table 2

[0027] In 6G, the target may go up to 400MHz or 500MHz, thus, 2x, 4x, or 5x larger allocation sizes. Following the same allocation principle for wide bandwidths, Table 3 below provides 43 new PRB aligned DFT sizes for a 500MHz case, thereby increasing Tx and Rx complexity, as well as unnecessary flexibility in the wide bandwidth operation, also

15 increasing scheduling complexity overhead.

1	2	3	4	5	6	8	9	10	12	15	16	18
20	24	25	27	30	32	36	40	45	48	50	54	60
64	72	75	80	81	90	96	100	108	120	125	128	135
144	150	160	162	180	192	200	216	225	240	243	250	256
270	288	300	320	324	360	375	384	400	405	432	450	480

486	500	512	540	576	600	625	640	648	675	720	729	750
768	800	810	864	900	960	972	1000	1024	1080	1125	1152	1200
1215	1250	1280	1296	1350								

Table 3

[0028] Table 4 below provides possible DFT sizes $L > 3240$ ($=12 \times 270$) according to Equation 1 above (i.e., $L_{\text{PRB}} = 2^a \times 3^b \times 5^c$), and the MHz usage assuming 30kHz SCS.

DFT size (L)	L/12 (PRB)	L*30kHz z (MHz)	DFT size (L)	L/12 (PRB)	L*30kHz z (MHz)	DFT size (L)	L/12 (PRB)	L*30kHz z (MHz)
3375	281.3	101.2	6144	512	184.3	10368	864	311
3456	288	103.6	6250	520.9	187.5	10800	900	324
3600	300	108	6400	533.4	192	10935	911.3	328
3645	303.8	109.3	6480	540	194.4	11250	937.5	337.5
3750	312.5	112.5	6561	546.8	196.8	11520	960	345.6
3840	320	115.2	6750	562.5	202.5	11664	972	349.9
3888	324	116.6	6912	576	207.3	12000	1000	360
4000	333.4	120	7200	600	216	12150	1012.5	364.5
4050	337.5	121.5	7290	607.5	218.7	12288	1024	368.6
4096	341.4	122.8	7500	625	225	12500	1041.7	375
4320	360	129.6	7680	640	230.4	12800	1066.7	384
4374	364.5	131.2	7776	648	233.2	12960	1080	388.8
4500	375	135	8000	666.7	240	13122	1093.5	393.6
4608	384	138.2	8100	675	243	13500	1125	405
4800	400	144	8192	682.7	245.7	13824	1152	414.7
4860	405	145.8	8640	720	259.2	14400	1200	432
5000	416.7	150	8748	729	262.4	14580	1215	437.4
5120	426.7	153.6	9000	750	270	15000	1250	450
5184	432	155.5	9216	768	276.4	15360	1280	460.8
5400	450	162	9375	781.3	281.2	15552	1296	466.5
5625	468.8	168.7	9600	800	288	15625	1302.1	468.7
5760	480	172.8	9720	810	291.6	16000	1333.4	480
5832	486	174.9	10000	833.4	300	16200	1350	486
6000	500	180	10125	843.8	303.7	16384	1365.4	491.5
6075	506.3	182.2	10240	853.4	307.2			

Table 4

[0029] Thus, it is desirable to design DFT-s-OFDM allocation options for wide bandwidth operation to minimize new implementation efforts and avoid unnecessary complexity, while still giving sufficient opportunities for using DFT-s-OFDM for coverage limited scenarios.

[0030] Certain example embodiments described herein may have various benefits and/or advantages to overcome the disadvantages described above. For example, certain example embodiments may determine valid allocation size or allocation bandwidth (in terms of *e.g.*, number of PRBs, number of REs, or number of subcarriers) for DFT-s-OFDM, specifically, the conditions for determining validity of DFT-s-OFDM allocation options depending on allocation size. Furthermore, some example embodiments may avoid unnecessary complexity/implementation effort of DFT-s-OFDM for 6G wideband operations, while providing enough flexibility for scheduling. Various example embodiments may also enable simple extensions and combinations of existing DFT/FFT implementations. For example, since the number of legacy allocation options is 53, it may be efficient to limit the number of added allocation options to 11 or less. In this example, six bits may be sufficient to indicate up to 64 allocation options. Thus, certain example embodiments discussed below are directed to improvements in computer-related technology.

[0031] In certain example embodiments, a UE may determine valid allocation sizes or allocation bandwidths for DFT-s-OFDM within a maximum CBW. In certain example embodiments, the conditions for determining the validity of DFT-s-OFDM allocation options may depend on allocation size in terms of number of PRBs. For example, when a number of PRBs is at or below a threshold (*e.g.*, 275), a first set of conditions may be applied for determining the validity of the DFT-s-OFDM allocation option of this number of PRBs, wherein the allocation option is determined to be valid as long as the number of PRBs L_{PRB} satisfies $L_{\text{PRB}} = 2^a \times 3^b \times 5^c$. However, when the number of PRBs is above the threshold (*e.g.*, 275), a second set of conditions may be applied for determining the validity of the DFT-s-OFDM allocation option of this number of PRBs. In other words, the DFT-s-OFDM allocation option of a number of PRBs is valid if the allocation option belongs to a subset of all the possible allocation options satisfying $L_{\text{PRB}} = 2^a \times 3^b \times 5^c$, and determined based on the second set of conditions.

[0032] In certain example embodiments (denoted as Option 1), the second set of conditions may include choosing a subset to be an integer multiple of existing configurations (*e.g.*, those

sizes for which $L'_{\text{PRB}} = 2^a \times 3^b \times 5^c$ and $L'_{\text{PRB}} \leq 275$, *e.g.*, the values shown in Table 1 above), and the supported PRB sizes may be selected for example as a) $2 \times L'_{\text{PRB}}$, b) $3 \times L'_{\text{PRB}}$, c) $5 \times L'_{\text{PRB}}$, d) $2 \times L'_{\text{PRB}}$ and $3 \times L'_{\text{PRB}}$, e) $2 \times L'_{\text{PRB}}$ and $5 \times L'_{\text{PRB}}$, or f) $3 \times L'_{\text{PRB}}$ and $5 \times L'_{\text{PRB}}$.

- 5 **[0033]** In some example embodiments (denoted as Option 2), the second set of conditions may include choosing a subset based on configurations which are divisible by a predefined number, such as, for example, a predefined resource block group (RBG) size. As an example, RBG size may be 16, 32, or 64 PRBs; alternatively, RBG size may be 50 or 100 PRBs. As another example, the subset may be chosen from all options satisfying $L_{\text{PRB}} =$
 10 $2^a \times 3^b \times 5^c$, and being divisible by RBG size and/or from all options satisfying any subset of $2 \times L_{\text{PRB}}$, $3 \times L_{\text{PRB}}$, $5 \times L_{\text{PRB}}$, $2 \times L_{\text{PRB}}$ and $3 \times L_{\text{PRB}}$; $2 \times L_{\text{PRB}}$ and $5 \times L_{\text{PRB}}$, or $3 \times L_{\text{PRB}}$ and $5 \times L_{\text{PRB}}$, and being divisible by RBG size.

- [0034]** In various example embodiments (denoted as Option 3), the second set of conditions may include choosing a subset based on allocations $L_{\text{PRB}} = 2^a \times 3^b \times 5^c$, where the number
 15 of PRBs is less than or equal to a given maximum PRB limit ($L_{\text{max,PRB}}$) within the CBW ($L_{\text{PRB}} \leq L_{\text{max,PRB}}$). Thus, the maximum allocation size may be limited. The maximum PRB limit may vary according to scenario (*e.g.*, CBW, FR, UE capability). As an example, CBW may be 550 PRB, and the resulting subset may include all combinations satisfying 288, 300, 320, 324, 360, 375, 384, 400, 405, 432, 450, 480, 486, 500, 512, and 540. The supported
 20 subset for maximum of 512 PRBs (*i.e.*, $L_{\text{max,PRB}} = 512$) may include each value except 540.

[0035] In certain example embodiments (denoted as Option 4), the second set of conditions may include choosing a subset such that only powers of 2, or powers of 3, or powers of 5 are possible.

- 25 **[0036]** In some example embodiments (denoted as Option 5), the second set of conditions may include choosing a subset with a starting number of PRBs, X , and granularity of PRBs, Y , according to equation $Z_i = X + iY$, $i = 0, 1, \dots, J$ for evaluating the PRB size subset, where Z_i may be the candidate allocation size. If the i^{th} candidate size $Z_i = X + iY$ cannot be represented as $L_{\text{PRB}} = 2^a \times 3^b \times 5^c$, the i^{th} candidate size may not be supported. Instead,
 30 a nearest valid option satisfying $L_{\text{PRB}} = 2^a \times 3^b \times 5^c$, a next larger (*e.g.*, full PRB) option satisfying $L_{\text{PRB}} = 2^a \times 3^b \times 5^c$, or a next smaller (*e.g.*, full PRB) option satisfying $L_{\text{PRB}} =$

$2^a \times 3^b \times 5^c$ may be supported. The difference between $X + iY$ and the nearest smaller allocation (*e.g.*, full PRB) satisfying $L_{\text{PRB}} = 2^a \times 3^b \times 5^c$ may be considered as “empty” resource elements (REs) or spectrum extension REs.

[0037] As an illustrative example, partial PRBs or different PRB sizes may be used to achieve at least nearly $X + iY$ PRBs. The starting point may be that the allocation size in terms of REs (*e.g.*, $2^a \times 3^b \times 5^c$ REs) needs to create one or more full PRBs, but without being constructed of only full PRBs. In addition to one or more full PRBs, there may be one partial PRB with a few unused REs, or one PRB with a smaller number of REs compared to a full PRB.

[0038] In another illustrative example, $X = 256$, and $Y = 32$ so as to provide as much equally divided granularity as possible. Thus, $Z_1 = 256 + 1 * 32 = 288$, $Z_2 = 256 + 2 * 32 = 320$, and $Z_3 = 256 + 3 * 32 = 352$ (not representable as $L_{\text{PRB}} = 2^a \times 3^b \times 5^c$). This 352 may be rounded to the nearest valid size of 360. It is noted that X may be any integer, such as 256 or 270.

[0039] In various example embodiments (denoted as Option 6), the second set of conditions may include choosing a subset such that the subset includes every n^{th} allocation option satisfying $L_{\text{PRB}} = 2^a \times 3^b \times 5^c$ or every n^{th} element of the ascendingly-ordered elements of any subset above, where n is a positive integer.

[0040] In certain example embodiments (denoted as Option 7), the second set of conditions may include choosing a subset based on expected operator bandwidth allocation to enable maximum full outer and optionally inner allocations. For example, bandwidth may be in increments of 10 MHz from 100 MHz to 200 MHz (*i.e.*, 100, 110, ..., 190, 200 MHz), followed by increments of 50 MHz above 200 MHz (*i.e.*, 200, 250, 300, etc.). As shown in Table 5 below, the closest smaller valid PRB option may be chosen according to 10MHz steps for up to 200MHz, and according to 50MHz steps from 200 to 400MHz.

Bandwidth region	Supported PRBs (and bandwidth in MHz)									
	300	324	360	384	405	432	450	500	512	540
100-200MHz	(108 MHz)	(116.6 MHz)	(129.6 MHz)	(138.2 MHz)	(145.8 MHz)	(155.5 MHz)	(162 MHz)	(180 MHz)	(184.3 MHz)	(194.4 MHz)

200-400MHz	675 (243 MHz)	810 (291.6 MHz)	972 (349.9 MHz)	1080 (388.8 MHz)						
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Table 5

[0041] In various example embodiments (denoted as Option 8), the second set of conditions may include choosing a subset based on allocations $L_{PRB} = 2^a \times 3^b \times 5^c$, with a predefined or configured combination of $\{a, b, c\}$, such as for example, any $\{a, b, 0\}$, or $\{a, 0, c\}$.

- 5 **[0042]** In certain example embodiments, the various options illustrated above may be applied in any combination. In a further example embodiment, the second condition may be applied up to given percentage or portion of the maximum possible supported bandwidth for CP-OFDM, *i.e.*, the maximum supported CBW for DFT-s-OFDM. For example, if the maximum supported CBW is 1100 PRBs, the second condition may be applied up to 50% of this (*i.e.*, up to 550 PRBs, which is the second threshold). As an alternative to the given percentage, the second threshold (*e.g.*, 550 PRBs) may be defined by specification or configured by the network, which may vary according to scenario (*e.g.*, FR). Restricting the maximum bandwidth for DFT-s-OFDM may also limit unnecessary implementation and/or scheduling complexity since some wideband allocations may be only used for CP-OFDM.
- 10
- 15 **[0043]** It is noted that, in above example embodiments, the allocation size in terms of number of PRBs has been used for illustrative purposes; the principles can be applied based on other metrics such as, for example, number of REs, number of subcarriers, and/or allocation bandwidth. In another further example embodiment, different conditions may be applied for the DFT-s-OFDM allocation options depending on the maximum CBW. For example, when the maximum CBW is equal to or below 100MHz, all allocation options L_{PRB} satisfying $L_{PRB} = 2^a \times 3^b \times 5^c$ may be supported, but when the maximum CBW is above 100MHz, the second set of conditions illustrated above may be applied.
- 20

- [0044]** Various example embodiments of Options 1 to 6 described above are summarized in Table 6 below when assuming maximum of 550 PRBs CBW for DFT-s-OFDM. Depending on the chosen second condition, different numbers of possible allocation options are available.
- 25

All possible options	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6a	Option 6b
$L=2^a \cdot 3^b \cdot 5^c$	Existing PRBs multiplied by 2	Multiple sizes of RBG size (=16)	All options up to 512	Power of 2	startPRB = 256, granularity = 32, round to nearest	Every 2 nd	Every 2 nd of multiple sizes of RBG size (=16)
288	288	288	288	512	288	288	288
300	300	320	300	-	320	320	384
320	320	384	320	-	360	360	432
324	324	400	324	-	384	384	512
360	360	432	360	-	405	405	-
375	384	480	375	-	450	450	-
384	400	512	384	-	480	486	-
400	432	-	400	-	512	512	-
405	450	-	405	-	-	-	-
432	480	-	432	-	-	-	-
450	486	-	450	-	-	-	-
480	500	-	480	-	-	-	-
486	512	-	486	-	-	-	-
500	-	-	500	-	-	-	-
512	-	-	512	-	-	-	-
540	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-

Table 6

[0045] FIG. 3 illustrates an example of a flow diagram of a method 300 that may be performed by a UE, such as UE 520 illustrated in FIG. 5, according to various example embodiments.

[0046] At step 301, the method may include receiving a UL grant for DFT-s-OFDM (*e.g.*, physical uplink shared channel (PUSCH)). For example, the UL grant may be downlink control information (DCI) format 0_0, DCI 0_1 (*i.e.*, involving physical downlink control channel (PDCCH) blind detection) or a higher layer configuration for semi-persistent allocation.

[0047] At step 302, the method may further include determining an allocation size (*e.g.*, in PRBs). For example, this may be determined from a FDRA field containing both location and size.

[0048] At step 303, the method may further include determining if the allocation size is equal to or smaller than a predefined threshold (*i.e.*, first threshold). In certain example embodiments, the first threshold may be any value between 271 and 276 PRBs, such as 275 PRBs.

[0049] If the allocation size is determined to be equal to or smaller than the predefined threshold at step 303, at step 305, the method may further include determining the validity of allocation size according to a first condition.

[0050] If the allocation size is determined to be larger than the predefined threshold at step 303, at step 304, the method may optionally further include determining if the allocation size is greater than a predefined threshold (*i.e.*, second threshold). In some example embodiments, the second threshold may be determined by a predefined parameter in specifications or configured by network (*e.g.*, 550). The predefined parameter may also depend on any of the CBW, FR, or other conditions. In various example embodiments, the second threshold may be determined based on a predefined fraction of the CBW size. For example, the fraction may be 50% of the maximum number of PRBs available in certain predefined scenario (*e.g.*, 400 MHz with 30 kHz SCS).

[0051] If the allocation size is determined to not be larger than the second threshold at step 304, at step 306, the method may include determining if the allocation size is valid according to a second condition. The second condition may include any of the various embodiments described above (*e.g.*, second set of conditions). In particular, the UE may determine whether the bandwidth of a PUSCH/uplink data channel in terms of allocated PRBs satisfies a condition.

[0052] If the allocation size is determined to be larger than the second threshold at step 304, if the allocation size is determined to be invalid at step 305, and/or if the allocation size is determined to be invalid at step 306, the allocation may be considered as invalid for DFT-s-OFDM at 307. The UE may then ignore the UL grant (*e.g.*, the UE may drop the allocation).

5 Alternatively, if the allocation size is determined to be invalid at step 306, the allocation size may be modified to be a valid allocation size. The modification can be done by rounding the allocation size down to the largest integer according to the 2nd condition to obtain a modified allocation size that is valid. In this case, the actual PRBs used for transmission may be the lowest-indexed PRBs of the frequency domain resource allocation (or alternatively, the
10 highest-indexed PRBs of the frequency domain resource allocation). After those operations, the allocation size originally determined to be invalid (at step 306) may be considered to be a valid allocation size.

[0053] If the allocation size is determined to be valid at step 305 and/or 306, the allocation may be considered as valid for DFT-s-OFDM at 308. The UE may then transmit PUSCH
15 according to a valid UL grant.

[0054] FIG. 4 illustrates an example of a flow diagram of a method 400 that may be performed by a UE, such as UE 520 illustrated in FIG. 5, according to various example embodiments.

[0055] At step 401, the method may include determining, by the UE, whether a number of
20 PRBs of a data channel is greater than a threshold.

[0056] At step 402, the method may further include, based upon the determination that the number of PRBs is greater than the threshold, determining, by the UE, validity of at least one allocation option for PRBs of the data channel based on a condition. The at least one allocation option may define a bandwidth of the data channel in terms of the number of
25 PRBs.

[0057] At step 403, the method may further include transmitting, by the UE, the data channel according to at least one valid allocation option.

[0058] In certain example embodiments, the condition may be defined such that the at least one allocation option is determined to be valid if the number of PRBs is an integer multiple
30 of an existing valid PRB allocation size.

[0059] In some example embodiments, the condition may be defined such that the at least one allocation option is determined to be valid if the number of PRBs comprises an existing valid PRB allocation size that is divisible by a predefined number. The predefined number may be a resource block group size.

- 5 [0060] In various example embodiments, the condition may be defined such that the at least one allocation option is determined to be valid if the number of PRBs is less than or equal to a maximum PRB limit. The maximum PRB limit may include a predefined maximum number of PRBs, a number of PRBs of a maximum channel bandwidth, a number of PRBs of a maximum PRB allocation size for the data channel, and/or a variable according to at least one of a scenario, a frequency range, or at least one capability of a UE.

[0061] In certain example embodiments, the condition may be defined such that the at least one allocation option is determined to be valid if the number of PRBs is a power of an integer. The integer may be 2, 3, or 5.

- 15 [0062] In some example embodiments, the method may further include selecting an initial number and granularity of PRBs. Determining the validity of the at least one allocation option may include evaluating the allocation option based upon the initial number and the granularity.

- [0063] In various example embodiments, the condition may be defined such that the at least one allocation option is determined to be valid if the number of PRBs includes one of every n^{th} existing valid PRB allocation size.

[0064] In certain example embodiments, the condition may be defined such that the at least one allocation option is determined to be valid if the number of PRBs includes a PRB allocation size fulfilling an expected operator bandwidth allocation.

- 25 [0065] In some example embodiments, the condition may be defined such that the at least one allocation option is determined to be valid if the number of PRBs includes a PRB allocation size fulfilling $2^a \times 3^b \times 5^c$ with a predefined or configured combination of $\{a, b, c\}$, wherein a , b , and c are non-negative integers.

- [0066] In various example embodiments, the existing valid PRB allocation size may fulfill $2^a \times 3^b \times 5^c$, wherein a , b , and c are non-negative integers. The existing valid PRB allocation size may be less than or equal to the threshold.

[0067] In certain example embodiments, the method may further include determining a number of subcarriers/resource elements of a transform precoder based upon the bandwidth of the data channel.

5 [0068] In some example embodiments, the number of PRBs may be provided by frequency domain resource allocation of an uplink grant. The uplink grant may be included in at least one of DCI signaling, radio resource control (RRC) signaling, or medium access control (MAC) signaling.

[0069] In various example embodiments, the method may further include, upon determining that there is no valid allocation option, preventing transmission of the data channel.

10 [0070] In certain example embodiments, the method may further include, upon determining that an allocation option is invalid, modifying the allocation option by rounding the number of PRBs to a different number of PRBs that fulfills the condition, to obtain a modified allocation option. The transmitting of the data channel may include transmitting the data channel according to the modified allocation option.

15 [0071] In some example embodiments, the threshold may be predetermined by a specification requirement or configured by a network entity, such as NE 510 illustrated in FIG. 5.

[0072] In various example embodiments, the determining of the validity of the at least one allocation option may be based on the number of PRBs being below or equal to a second threshold. The second threshold may be determined as at least one of a percentage of a maximum channel bandwidth, a percentage of bandwidth available for cyclic prefix-OFDM in a unit of PRBs, a threshold predetermined by a specification requirement, and/or a threshold configured by a network entity, such as NE 510 illustrated in FIG. 5.

25 [0073] FIG. 5 illustrates an example of a system according to certain example embodiments. In one example embodiment, a system may include multiple devices, such as, for example, NE 510 and/or UE 520.

[0074] NE 510 may be one or more of a base station (*e.g.*, 3G UMTS NodeB, 4G LTE Evolved NodeB, or 5G NR Next Generation NodeB), a serving gateway, a server, and/or any other access node or combination thereof.

30 [0075] NE 510 may further include at least one gNB-centralized unit (CU), which may be associated with at least one gNB-distributed unit (DU). The at least one gNB-CU and the at

least one gNB-DU may be in communication via at least one F1 interface, at least one X_n-C interface, and/or at least one NG interface via a 5th generation core (5GC).

[0076] UE 520 may include one or more of a mobile device, such as a mobile phone, smart phone, personal digital assistant (PDA), tablet, or portable media player, digital camera, pocket
5 video camera, video game console, navigation unit, such as a global positioning system (GPS) device, desktop or laptop computer, single-location device, such as a sensor or smart meter, or any combination thereof. Furthermore, NE 510 and/or UE 520 may be one or more of a citizens broadband radio service device (CBSD).

[0077] NE 510 and/or UE 520 may include at least one processor, respectively indicated as 511
10 and 521. Processors 511 and 521 may be embodied by any computational or data processing device, such as a central processing unit (CPU), application specific integrated circuit (ASIC), or comparable device. The processors may be implemented as a single controller, or a plurality of controllers or processors.

[0078] At least one memory may be provided in one or more of the devices, as indicated at 512
15 and 522. The memory may be fixed or removable. The memory may include computer program instructions or computer code contained therein. Memories 512 and 522 may independently be any suitable storage device, such as a non-transitory computer-readable medium. The term “non-transitory,” as used herein, may correspond to a limitation of the medium itself (*i.e.*, tangible, not a signal) as opposed to a limitation on data storage
20 persistency (*e.g.*, random access memory (RAM) vs. read-only memory (ROM)). A hard disk drive (HDD), random access memory (RAM), flash memory, or other suitable memory may be used. The memories may be combined on a single integrated circuit as the processor, or may be separate from the one or more processors. Furthermore, the computer program instructions stored in the memory, and which may be processed by the processors, may be
25 any suitable form of computer program code, for example, a compiled or interpreted computer program written in any suitable programming language.

[0079] Processors 511 and 521, memories 512 and 522, and any subset thereof, may be configured to provide means corresponding to the various blocks of FIG. 3. Although not shown, the devices may also include positioning hardware, such as GPS or micro electrical
30 mechanical system (MEMS) hardware, which may be used to determine a location of the

device. Other sensors are also permitted, and may be configured to determine location, elevation, velocity, orientation, and so forth, such as barometers, compasses, and the like.

[0080] As shown in FIG. 5, transceivers 513 and 523 may be provided, and one or more devices may also include at least one antenna, respectively illustrated as 514 and 524. The device may have many antennas, such as an array of antennas configured for multiple input multiple output (MIMO) communications, or multiple antennas for multiple RATs. Other configurations of these devices, for example, may be provided. Transceivers 513 and 523 may be a transmitter, a receiver, both a transmitter and a receiver, or a unit or device that may be configured both for transmission and reception.

[0081] The memory and the computer program instructions may be configured, with the processor for the particular device, to cause a hardware apparatus, such as UE, to perform any of the processes described above (*i.e.*, FIG. 3). Therefore, in certain example embodiments, a non-transitory computer-readable medium may be encoded with computer instructions that, when executed in hardware, perform a process such as one of the processes described herein. Alternatively, certain example embodiments may be performed entirely in hardware.

[0082] In certain example embodiments, an apparatus may include circuitry configured to perform any of the processes or functions illustrated in FIG. 3. As used in this application, the term “circuitry” may refer to one or more or all of the following: (a) hardware-only circuit implementations (such as implementations in only analog and/or digital circuitry), (b) combinations of hardware circuits and software, such as (as applicable): (i) a combination of analog and/or digital hardware circuit(s) with software/firmware and (ii) any portions of hardware processor(s) with software (including digital signal processor(s)), software, and memory(ies) that work together to cause an apparatus, such as a mobile phone or server, to perform various functions), and (c) hardware circuit(s) and or processor(s), such as a microprocessor(s) or a portion of a microprocessor(s), that requires software (*e.g.*, firmware) for operation, but the software may not be present when it is not needed for operation. This definition of circuitry applies to all uses of this term in this application, including in any claims. As a further example, as used in this application, the term circuitry also covers an implementation of merely a hardware circuit or processor (or multiple processors) or portion of a hardware circuit or processor and its (or their) accompanying software and/or firmware.

The term circuitry also covers, for example and if applicable to the particular claim element, a baseband integrated circuit or processor integrated circuit for a mobile device or a similar integrated circuit in server, a cellular network device, or other computing or network device.

[0083] FIG. 6 illustrates an example of a 5G network and system architecture according to certain example embodiments. Shown are multiple network functions that may be implemented as software operating as part of a network device or dedicated hardware, as a network device itself or dedicated hardware, or as a virtual function operating as a network device or dedicated hardware. The NE and UE illustrated in FIG. 6 may be similar to NE 510 and UE 520, respectively. The user plane function (UPF) may provide services such as intra-RAT and inter-RAT mobility, routing and forwarding of data packets, inspection of packets, user plane quality of service (QoS) processing, buffering of downlink packets, and/or triggering of downlink data notifications. The application function (AF) may primarily interface with the core network to facilitate application usage of traffic routing and interact with the policy framework.

[0084] According to certain example embodiments, processors 511 and 521, and memories 512 and 522, may be included in or may form a part of processing circuitry or control circuitry. In addition, in some example embodiments, transceivers 513 and 523 may be included in or may form a part of transceiving circuitry.

[0085] In some example embodiments, an apparatus (*e.g.*, NE 510 and/or UE 520) may include means for performing a method, a process, or any of the variants discussed herein. Examples of the means may include one or more processors, memory, controllers, transmitters, receivers, and/or computer program code for causing the performance of the operations.

[0086] In various example embodiments, apparatus 510/520 may be controlled by memory 512/522 and processor 511/521 to determine whether a number of PRBs of a data channel is greater than a threshold; based upon the determination that the number of PRBs is greater than the threshold, determine validity of at least one allocation option for PRBs of the data channel based on a condition; transmit the data channel according to at least one valid allocation option. The at least one allocation option defines a bandwidth of the data channel in terms of the number of PRBs.

[0087] Certain example embodiments may be directed to an apparatus that includes means for performing any of the methods described herein including, for example, means for

determining whether a number of PRBs of a data channel is greater than a threshold; based upon the determination that the number of PRBs is greater than the threshold, means for determining validity of at least one allocation option for PRBs of the data channel based on a condition; and means for transmitting the data channel according to at least one valid allocation option. The at least one allocation option defines a bandwidth of the data channel in terms of the number of PRBs.

[0088] The features, structures, or characteristics of example embodiments described throughout this specification may be combined in any suitable manner in one or more example embodiments. For example, the usage of the phrases “various embodiments,” “certain embodiments,” “some embodiments,” or other similar language throughout this specification refers to the fact that a particular feature, structure, or characteristic described in connection with an example embodiment may be included in at least one example embodiment. Thus, appearances of the phrases “in various embodiments,” “in certain embodiments,” “in some embodiments,” or other similar language throughout this specification does not necessarily all refer to the same group of example embodiments, and the described features, structures, or characteristics may be combined in any suitable manner in one or more example embodiments.

[0089] As used herein, “at least one of the following: <a list of two or more elements>” and “at least one of <a list of two or more elements>” and similar wording, where the list of two or more elements are joined by “and” or “or,” mean at least any one of the elements, or at least any two or more of the elements, or at least all the elements.

[0090] Additionally, if desired, the different functions or procedures discussed above may be performed in a different order and/or concurrently with each other. Furthermore, if desired, one or more of the described functions or procedures may be optional or may be combined. As such, the description above should be considered as illustrative of the principles and teachings of certain example embodiments, and not in limitation thereof.

[0091] One having ordinary skill in the art will readily understand that the example embodiments discussed above may be practiced with procedures in a different order, and/or with hardware elements in configurations which are different than those which are disclosed. Therefore, although some embodiments have been described based upon these example embodiments, it would be apparent to those of skill in the art that certain modifications, variations, and alternative constructions would be apparent, while remaining within the spirit

and scope of the example embodiments. For example, while the example embodiments have been described above in the context of DFT-s-OFDM in uplink transmission, it should be appreciated that the example embodiments described herein are not limited for use with only this one particular type of communication, and that they may be used in downlink or sidelink transmission, and/or with any type of DFT/FFT/IFFT based waveform.

[0092] Partial Glossary

	[0093]	3GPP	3 rd Generation Partnership Project
	[0094]	5G	5 th Generation
	[0095]	5GC	5 th Generation Core
10	[0096]	6G	6 th Generation
	[0097]	ACLR	Adjacent Channel Leakage Ratio
	[0098]	AF	Application Function
	[0099]	ASIC	Application Specific Integrated Circuit
	[0100]	BPSK	Binary Phase Shift Keying
15	[0101]	BW	Bandwidth
	[0102]	CBSD	Citizens Broadband Radio Service Device
	[0103]	CBW	Channel Bandwidth
	[0104]	CP	Cyclic Prefix
	[0105]	CPU	Central Processing Unit
20	[0106]	CU	Centralized Unit
	[0107]	DCI	Downlink Control Information
	[0108]	DFT	Discrete Fourier Transform
	[0109]	DFT-s-OFDM Multiplexing	Discrete Fourier Transform spread Orthogonal Frequency Division Multiplexing
25	[0110]	DL	Downlink
	[0111]	DU	Distributed Unit
	[0112]	eMBB	Enhanced Mobile Broadband
	[0113]	eNB	Evolved Node B
	[0114]	EVM	Error Vector Magnitude
30	[0115]	FCC	Federal Communications Commission
	[0116]	FDRA	Frequency Domain Resource Allocation

	[0117]	FDSS	Frequency Domain Spectral Shaping
	[0118]	FFT	Fast Fourier Transform
	[0119]	FR	Frequency Range
	[0120]	gNB	Next Generation Node B
5	[0121]	GPS	Global Positioning System
	[0122]	HDD	Hard Disk Drive
	[0123]	IBE	In-band Emissions
	[0124]	IDFT	Inverse Discrete Fourier Transform
	[0125]	IFFT	Inverse Fast Fourier Transform
10	[0126]	IoT	Internet of Things
	[0127]	LTE	Long-Term Evolution
	[0128]	LTE-A	Long-Term Evolution Advanced
	[0129]	LUT	Look-up Table
	[0130]	MC	Multicarrier
15	[0131]	MCS	Modulation and Coding Scheme
	[0132]	MEMS	Micro Electrical Mechanical System
	[0133]	MIMO	Multiple Input Multiple Output
	[0134]	mMTC	Massive Machine Type Communication
	[0135]	MPR	Maximum Power Reduction
20	[0136]	NE	Network Entity
	[0137]	NG	Next Generation
	[0138]	NG-eNB	Next Generation Evolved Node B
	[0139]	NG-RAN	Next Generation Radio Access Network
	[0140]	NR	New Radio
25	[0141]	OBO	Output Back-Off
	[0142]	OBW	Occupied Bandwidth
	[0143]	OCDM	Orthogonal Chirp-Division Multiplexing
	[0144]	OFDM	Orthogonal Frequency-Division Multiplexing
	[0145]	OOB	Out-of-Band
30	[0146]	PA	Power Amplifier
	[0147]	PAPR	Peak-to-Average Power Ratio

	[0148]	PDA	Personal Digital Assistance
	[0149]	PDCCH	Physical Downlink Control Channel
	[0150]	PN	Phase Noise
	[0151]	PRB	Physical Resource Block
5	[0152]	PSD	Power Spectral Density
	[0153]	PSK	Phase-Shift Keying
	[0154]	PUSCH	Physical Uplink Shared Channel
	[0155]	QAM	Quadrature Amplitude Modulation
	[0156]	QoS	Quality of Service
10	[0157]	QPSK	Quadrature Phase Shift Keying
	[0158]	RAM	Random Access Memory
	[0159]	RAN	Radio Access Network
	[0160]	RAT	Radio Access Technology
	[0161]	RBG	Resource Block Group
15	[0162]	RE	Resource Element
	[0163]	ROM	Read-Only Memory
	[0164]	Rx	Receiver
	[0165]	SC-FDMA	Single-Carrier Frequency-Division Multiple Access
	[0166]	SCS	Subcarrier Spacing
20	[0167]	SEM	Spectral Emission Mask
	[0168]	TBW	Transmission Bandwidth
	[0169]	Tx	Transmission
	[0170]	UE	User Equipment
	[0171]	UL	Uplink
25	[0172]	UMTS	Universal Mobile Telecommunications System
	[0173]	UPF	User Plane Function
	[0174]	URLLC	Ultra-Reliable and Low-Latency Communication
	[0175]	UTRAN Access Network	Universal Mobile Telecommunications System Terrestrial Radio
30	[0176]	WOLA	Weighted Overlap-and-Add

WE CLAIM:

1. A method comprising:
determining whether a number of physical resource blocks of a data channel is greater than a threshold;
based upon the determination that the number of physical resource blocks is greater than the threshold, determining validity of at least one allocation option for physical resource blocks of the data channel based on a condition, wherein the at least one allocation option defines a bandwidth of the data channel in terms of the number of physical resource blocks; and
transmitting the data channel according to at least one valid allocation option.
2. The method of claim 1, wherein the condition is defined such that the at least one allocation option is determined to be valid if the number of physical resource blocks is an integer multiple of an existing valid physical resource block allocation size.
3. The method of claim 1 or 2, wherein the condition is defined such that the at least one allocation option is determined to be valid if the number of physical resource blocks comprises an existing valid physical resource block allocation size that is divisible by a predefined number.
4. The method of claim 3, wherein the predefined number is a resource block group size.
5. The method of any of claim 1 to 4, wherein the condition is defined such that the at least one allocation option is determined to be valid if the number of physical resource blocks is less than or equal to a maximum physical resource block limit.
6. The method of claim 5, wherein the maximum physical resource block limit comprises:
a predefined maximum number of physical resource blocks;

a number of physical resource blocks of a maximum channel bandwidth;
a number of physical resource blocks of a maximum physical resource block allocation size for the data channel; or
a variable according to at least one of a scenario, a frequency range, or at least one capability of a user equipment.

7. The method of any of claims 1 to 6, wherein the condition is defined such that the at least one allocation option is determined to be valid if the number of physical resource blocks is a power of an integer.

8. The method of claim 7, wherein the integer is 2, 3, or 5.

9. The method of any of claims 1 to 8, further comprising:
selecting an initial number and granularity of physical resource blocks, wherein determining of the validity of the at least one allocation option comprises:
evaluating the allocation option based upon the initial number and the granularity.

10. The method of any of claims 1 to 9, wherein the condition is defined such that the at least one allocation option is determined to be valid if the number of physical resource blocks comprises one of every n^{th} existing valid physical resource block allocation size.

11. The method of any of claims 1 to 10, wherein the condition is defined such that the at least one allocation option is determined to be valid if the number of physical resource blocks comprises a physical resource block allocation size fulfilling an expected operator bandwidth allocation.

12. The method of any of claims 1 to 11, wherein the condition is defined such that the at least one allocation option is determined to be valid if the number of physical resource blocks comprises a physical resource block allocation size fulfilling $2^a \times 3^b \times 5^c$ with a predefined or configured combination of $\{a, b, c\}$, wherein a , b , and c are non-negative integers.

13. The method of any of claims 1 to 12, wherein the existing valid physical resource block allocation size fulfills $2^a \times 3^b \times 5^c$, wherein a , b , and c are non-negative integers.

14. The method of claim 13, wherein the existing valid physical resource block allocation size is less than or equal to the threshold.

15. The method of any of claims 1 to 14, further comprising:
determining a number of subcarriers/resource elements of a transform precoder based upon the bandwidth of the data channel.

16. The method of any of claims 1 to 15, wherein the number of physical resource blocks is provided by frequency domain resource allocation of an uplink grant.

17. The method of claim 16, wherein the uplink grant is included in at least one of downlink control information signaling, radio resource control signaling, or medium access control signaling.

18. The method of any of claims 1 to 17, further comprising:
upon determining that there is no valid allocation option, preventing transmission of the data channel.

19. The method of any of claims 1 to 17, further comprising:
upon determining that an allocation option is invalid, modifying the allocation option by rounding the number of physical resource blocks to a different number of physical resource blocks that fulfills the condition, to obtain a modified allocation option, and wherein the transmitting of the data channel comprises transmitting the data channel according to the modified allocation option.

20. The method of any of claims 1 to 19, wherein the threshold is predetermined by

a specification requirement or configured by a network entity.

21. The method of any of claims 1 to 20, wherein the determining of the validity of the at least one allocation option is based on the number of physical resource blocks being below or equal to a second threshold, where the second threshold is determined as at least one of:

- a percentage of a maximum channel bandwidth;
- a percentage of bandwidth available for cyclic prefix-orthogonal frequency division multiplexing in a unit of physical resource blocks;
- a threshold predetermined by a specification requirement; or
- a threshold configured by a network entity.

22. An apparatus comprising:
at least one processor; and
at least one memory storing instructions that, when executed by the at least one processor, cause the apparatus at least to:

determine whether a number of physical resource blocks of a data channel is greater than a threshold;

based upon the determination that the number of physical resource blocks is greater than the threshold, determine validity of at least one allocation option for physical resource blocks of the data channel based on a condition, wherein the at least one allocation option defines a bandwidth of the data channel in terms of the number of physical resource blocks; and
transmit the data channel according to at least one valid allocation option.

23. An apparatus comprising:
means for determining whether a number of physical resource blocks of a data channel is greater than a threshold;
means for, based upon the determination that the number of physical resource blocks is greater than the threshold, determining validity of at least one allocation option for physical resource blocks of the data channel based on a condition, wherein the at least

one allocation option defines a bandwidth of the data channel in terms of the number of physical resource blocks; and

means for transmitting the data channel according to at least one valid allocation option.

24. The apparatus of claim 23, wherein the condition is defined such that the at least one allocation option is determined to be valid if the number of physical resource blocks is an integer multiple of an existing valid physical resource block allocation size.

25. The apparatus of claim 23 or 24, wherein the condition is defined such that the at least one allocation option is determined to be valid if the number of physical resource blocks comprises an existing valid physical resource block allocation size that is divisible by a predefined number.

26. The apparatus of claim 25, wherein the predefined number is a resource block group size.

27. The apparatus of any of claim 23 to 26, wherein the condition is defined such that the at least one allocation option is determined to be valid if the number of physical resource blocks is less than or equal to a maximum physical resource block limit.

28. The apparatus of claim 27, wherein the maximum physical resource block limit comprises:

a predefined maximum number of physical resource blocks;

a number of physical resource blocks of a maximum channel bandwidth;

a number of physical resource blocks of a maximum physical resource block allocation size for the data channel; or

a variable according to at least one of a scenario, a frequency range, or at least one capability of a user equipment.

29. The apparatus of any of claims 23 to 28, wherein the condition is defined such that the at least one allocation option is determined to be valid if the number of physical resource blocks is a power of an integer.

30. The apparatus of claim 29, wherein the integer is 2, 3, or 5.

31. The apparatus of any of claims 23 to 30, further comprising:
means for selecting an initial number and granularity of physical resource blocks,
wherein the means for determining of the validity of the at least one allocation option comprises:
means for evaluating the allocation option based upon the initial number and the granularity.

32. The apparatus of any of claims 23 to 31, wherein the condition is defined such that the at least one allocation option is determined to be valid if the number of physical resource blocks comprises one of every n^{th} existing valid physical resource block allocation size.

33. The apparatus of any of claims 23 to 32, wherein the condition is defined such that the at least one allocation option is determined to be valid if the number of physical resource blocks comprises a physical resource block allocation size fulfilling an expected operator bandwidth allocation.

34. The apparatus of any of claims 23 to 33, wherein the condition is defined such that the at least one allocation option is determined to be valid if the number of physical resource blocks comprises a physical resource block allocation size fulfilling $2^a \times 3^b \times 5^c$ with a predefined or configured combination of $\{a, b, c\}$, wherein a , b , and c are non-negative integers.

35. The apparatus of any of claims 23 to 34, wherein the existing valid physical resource block allocation size fulfills $2^a \times 3^b \times 5^c$, wherein a , b , and c are non-negative integers.

36. The apparatus of claim 35, wherein the existing valid physical resource block

allocation size is less than or equal to the threshold.

37. The apparatus of any of claims 23 to 36, further comprising:
means for determining a number of subcarriers/resource elements of a transform precoder based upon the bandwidth of the data channel.

38. The apparatus of any of claims 23 to 37, wherein the number of physical resource blocks is provided by frequency domain resource allocation of an uplink grant.

39. The apparatus of claim 38, wherein the uplink grant is included in at least one of downlink control information signaling, radio resource control signaling, or medium access control signaling.

40. The apparatus of any of claims 23 to 39, further comprising:
means for, upon determining that there is no valid allocation option, preventing transmission of the data channel.

41. The apparatus of any of claims 23 to 39, further comprising:
means for, upon determining that an allocation option is invalid, modifying the allocation option by rounding the number of physical resource blocks to a different number of physical resource blocks that fulfills the condition, to obtain a modified allocation option, and wherein the means for transmitting of the data channel comprises means for transmitting the data channel according to the modified allocation option.

42. The apparatus of any of claims 23 to 41, wherein the threshold is predetermined by a specification requirement or configured by a network entity.

43. The apparatus of any of claims 23 to 42, wherein the determining of the validity of the at least one allocation option is based on the number of physical resource blocks being below or equal to a second threshold, where the second threshold is determined as at least one

of:

- a percentage of a maximum channel bandwidth;
- a percentage of bandwidth available for cyclic prefix-orthogonal frequency division multiplexing in a unit of physical resource blocks;
- a threshold predetermined by a specification requirement; or
- a threshold configured by a network entity.

44. A computer program comprising instructions for causing an apparatus to perform at least the following:

- determining whether a number of physical resource blocks of a data channel is greater than a threshold;
- based upon the determination that the number of physical resource blocks is greater than the threshold, determining validity of at least one allocation option for physical resource blocks of the data channel based on a condition, wherein the at least one allocation option defines a bandwidth of the data channel in terms of the number of physical resource blocks; and
- transmitting the data channel according to at least one valid allocation option.

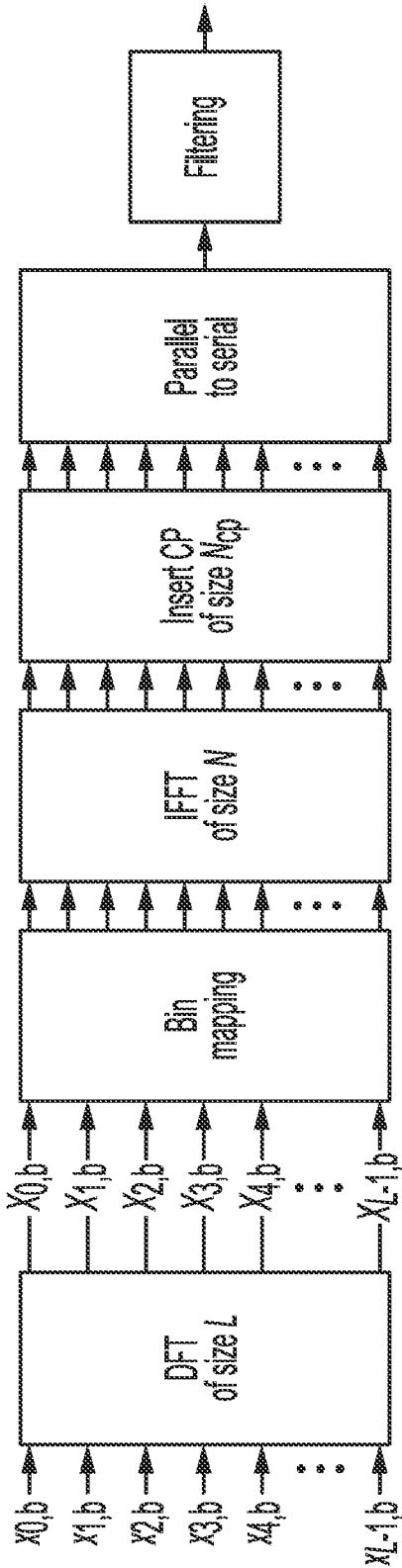


FIG. 1

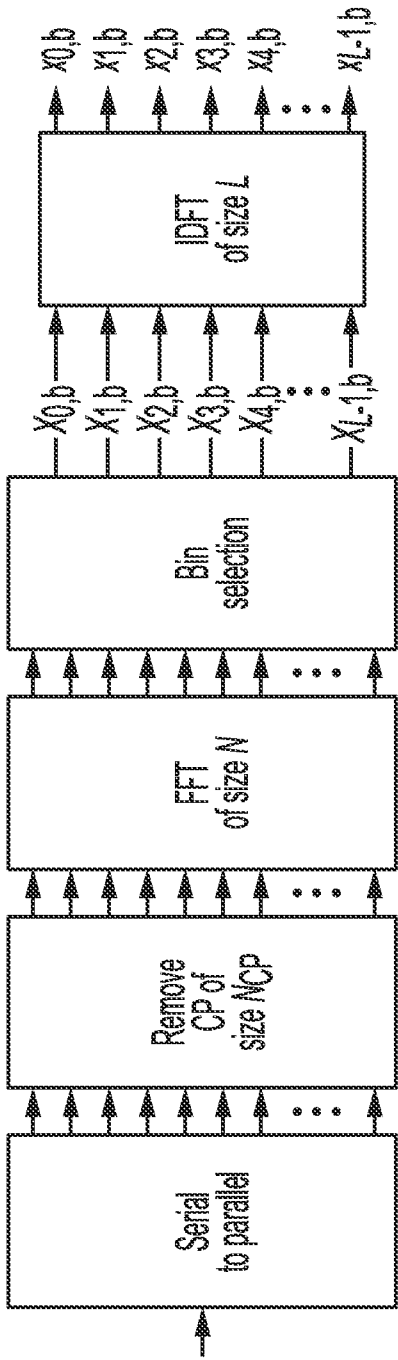


FIG. 2

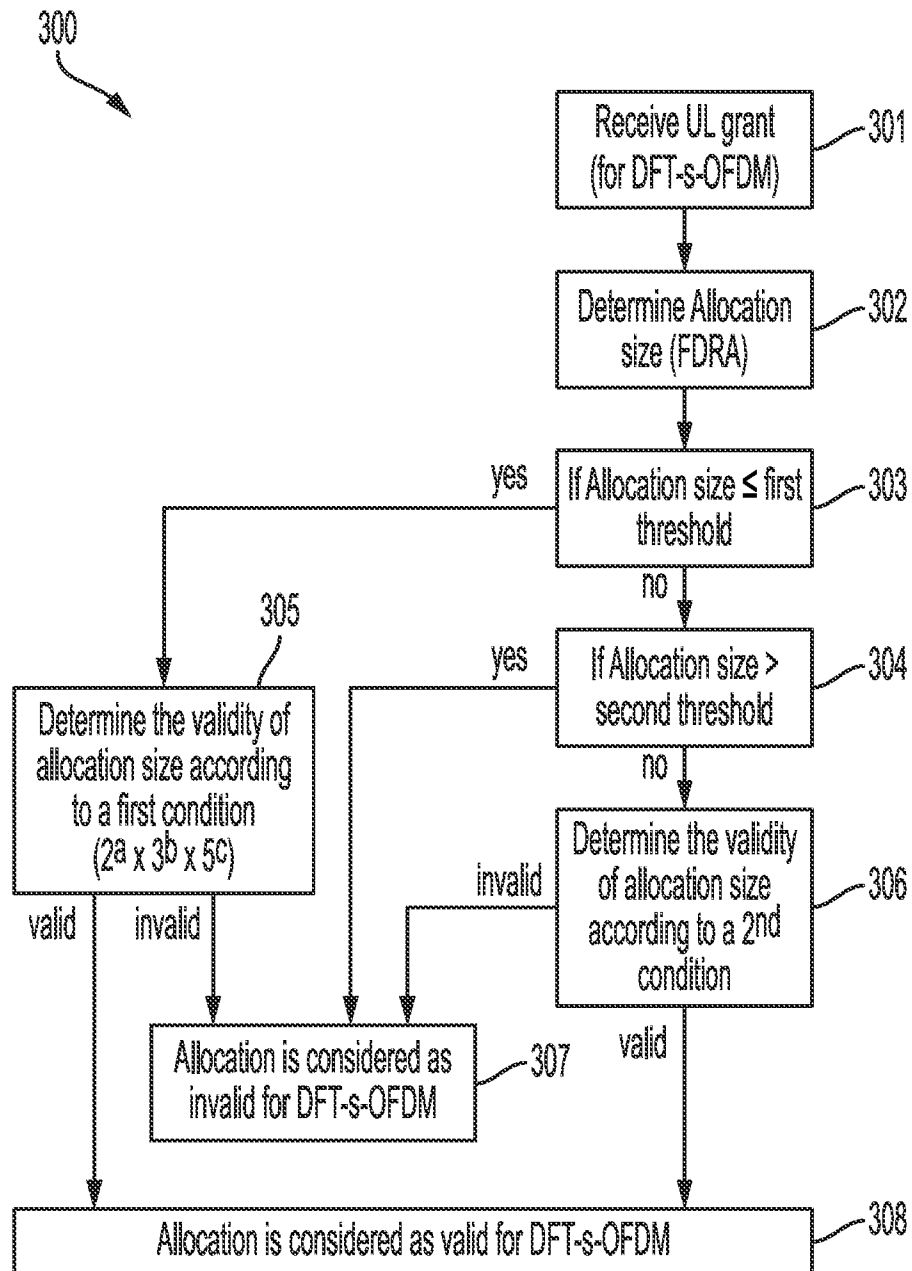


FIG. 3

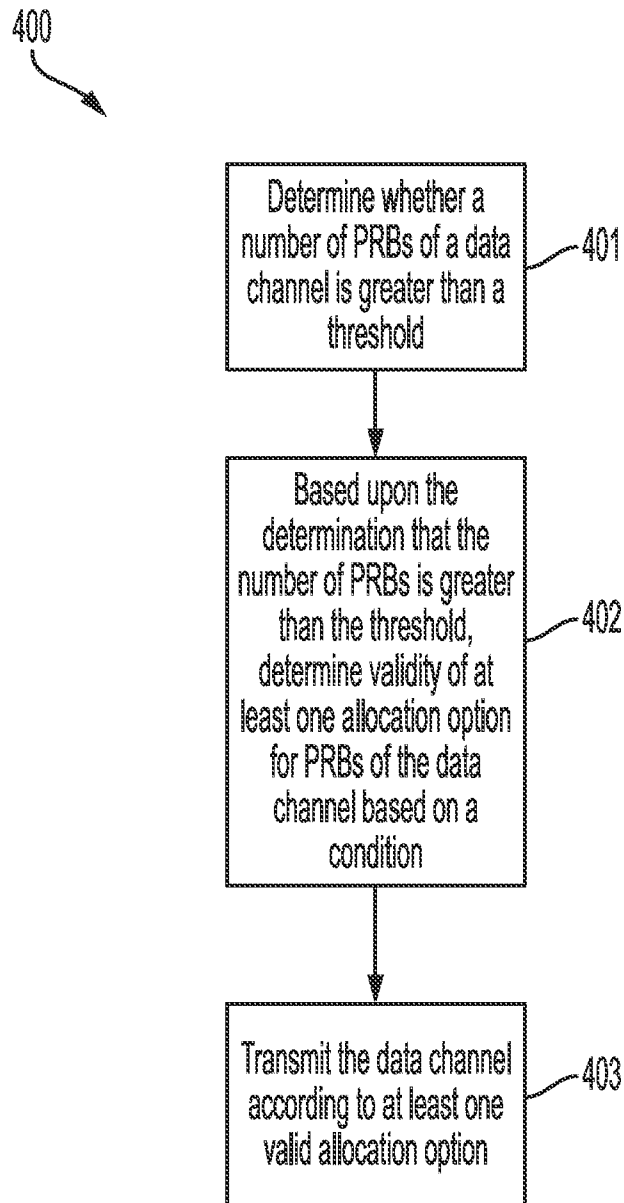


FIG. 4

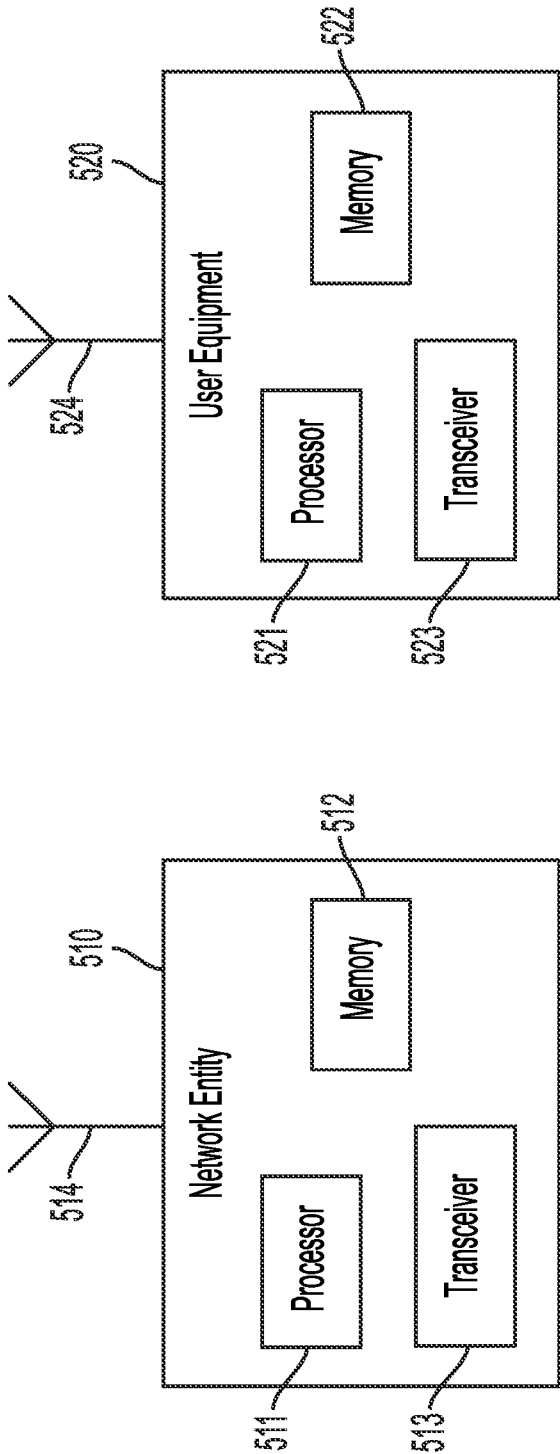
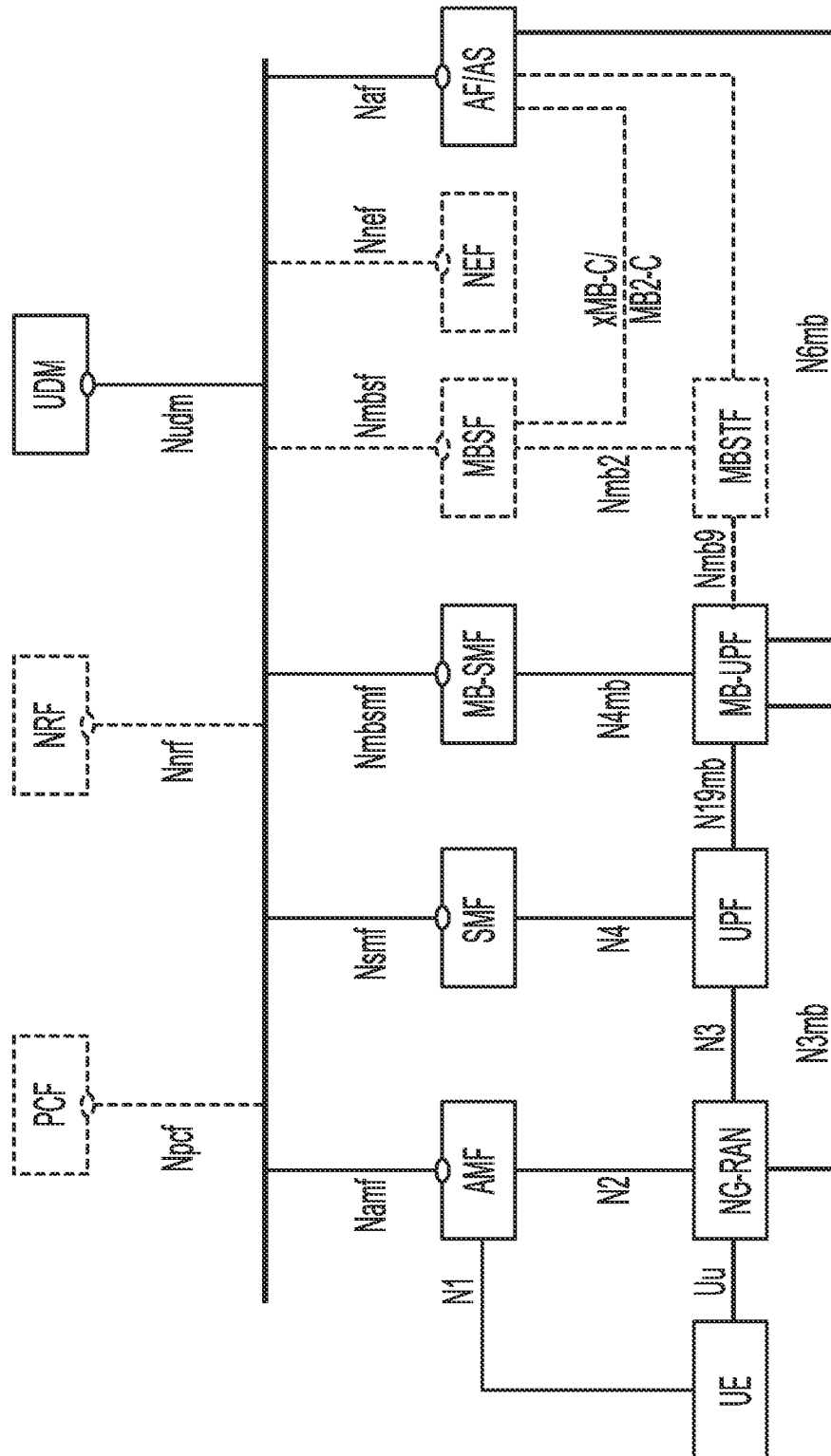


FIG. 5



INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2024/062336

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04L5/00 H04L27/26

ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04L

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2021/105774 A1 (OH JINYOUNG [KR] ET AL) 8 April 2021 (2021-04-08) paragraphs [0105], [0174] - [0218] figures 1-11 -----	1 - 44
X	US 2019/229967 A1 (FRANK COLIN [US]) 25 July 2019 (2019-07-25) paragraphs [0004] - [0005], [0030] - [0032], [0046] - [0082] -----	1 - 44



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

12 February 2025

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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