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(54) **Title:** EFFICIENT TRANSMISSION OF SYSTEM INFORMATION

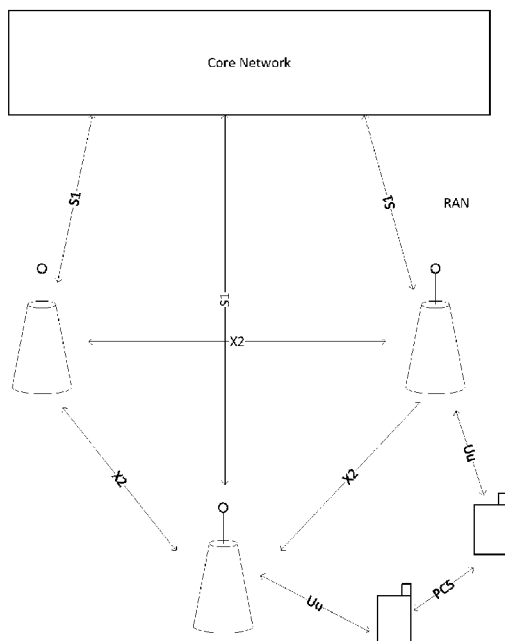


Figure 1

(57) **Abstract:** Methods for transmitting minimum system information from a base station in an OFDM transmission system. An MIB, in the form of a SS/PBCH block is multiplexed with RMSI information, which may include PDCCH and PDSCH, and the RMSI information is transmitted in the CORESET#0 frequency span. The SS/PBCH and the RMSI information occupy the same footprint in time but may comprise different number of OFDM symbols. The OFDM system may be operated in the licensed and unlicensed spectrum.



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## Efficient Transmission of System Information

### Technical Field

[1] The following disclosure relates to the transmission of system information in a wireless communication system, and more particularly for the transmission of minimum system information in high frequency operation.

### Background

[2] Wireless communication systems, such as the third-generation (3G) of mobile telephone standards and technology are well known. Such 3G standards and technology have been developed by the Third Generation Partnership Project (3GPP) (RTM). The 3rd generation of wireless communications has generally been developed to support macro-cell mobile phone communications. Communication systems and networks have developed towards a broadband and mobile system.

[3] In cellular wireless communication systems User Equipment (UE) is connected by a wireless link to a Radio Access Network (RAN). The RAN comprises a set of base stations which provide wireless links to the UEs located in cells covered by the base station, and an interface to a Core Network (CN) which provides overall network control. As will be appreciated the RAN and CN each conduct respective functions in relation to the overall network. For convenience the term cellular network will be used to refer to the combined RAN & CN, and it will be understood that the term is used to refer to the respective system for performing the disclosed function.

[4] The 3rd Generation Partnership Project has developed the so-called Long Term Evolution (LTE) system, namely, an Evolved Universal Mobile Telecommunication System Territorial Radio Access Network, (E-UTRAN), for a mobile access network where one or more macro-cells are supported by a base station known as an eNodeB or eNB (evolved NodeB). More recently, LTE is evolving further towards the so-called 5G or NR (new radio) systems where one or more cells are supported by a base station known as a gNB. NR is proposed to utilise an Orthogonal Frequency Division Multiplexed (OFDM) physical transmission format.

[5] The NR protocols are intended to offer options for operating in unlicensed radio bands, to be known as NR-U. When operating in an unlicensed radio band the gNB and UE must compete with other devices for physical medium/resource access. For example, Wi-Fi (RTM), NR-U, and LAA may utilise the same physical resources.

[6] A trend in wireless communications is towards the provision of lower latency and higher reliability services. For example, NR is intended to support Ultra-reliable and low-latency communications (URLLC) and massive Machine-Type Communications (mMTC) are intended to provide low latency and high reliability for small packet sizes (typically 32 bytes). A user-plane latency of 1ms has been proposed with a reliability of 99.99999%, and at the physical layer a packet loss rate of  $10^{-5}$  or  $10^{-6}$  has been proposed.

[7] mMTC services are intended to support a large number of devices over a long life-time with highly energy efficient communication channels, where transmission of data to and from each device occurs sporadically and infrequently. For example, a cell may be expected to support many thousands of devices.

[8] In NR a UE needs to decode minimum system information (MSI) broadcast by a base station to initiate any form of communication. The MSI is broadcast over a physical broadcast channel (PBCH) in the form of a master information block (MIB), which carries fundamental system information, and remaining system information (RMSI) as a system information block type

1 (SIB1). The control resource set (CORESET) configured through the MIB is called CORESET#0 is used to transmit downlink control information (DCI) which indicates the resources scheduled for the physical downlink shared channel (PDSCH) carrying the SIB1.

[9] To initiate communications a UE decodes a MIB as part of a cell search procedure, which enables the UE to acquire time and frequency synchronization with a base station, and the detect the physical layer cell identifier (ID). The UE receives synchronisation signals (SS) in the form of primary synchronisation signal (PSS) and a secondary synchronization signal (SSS) which are consecutive signals that together define a physical broadcast channel (PBCH) and form a SS/PBCH block. By decoding the PBCH, the UE is able to decode the MIB to complete configuration and receive and initiate downlink (DL) and uplink (UL) communications respectively.

[10] The disclosure below relates to various improvements to cellular wireless communications systems.

### Summary

[11] The invention is defined by the claims in which there is provided a method of transmitting minimum system information from a base station in an OFDM transmission system, the method comprising the steps of: transmitting an MIB in the form of a SS/PBCH block and RMSI information on at least one channel; wherein the transmitting step includes multiplexing the SS/PBCH with the RMSI information; and transmitting the RMSI information in the CORESET#0 frequency span.

[12] The RMSI information may include at least SIB1 RMSI PDCCH and/or PDSCH channel.

[13] The SS/PBCH may be transmitted over a number  $n$  of at least one OFDM symbol and the RMSI SIB1 is transmitted over a number  $m$  of at least one OFDM symbol, and wherein  $n$  is a multiple of  $m$ .

[14] The SS/PBCH may be transmitted over a number  $n$  of at least one OFDM symbol and the RMSI SIB1 is transmitted over a number  $m$  of at least one OFDM symbol, and wherein  $n$  is equal to  $m$ .

[15] The multiplexing step may comprise multiplexing in time.

[16] The OFDM system may operate in both licensed and unlicensed spectrum.

[17] SCS of the channel carrying the SS/PBCH block may be a multiple of the SCS of the channel carrying the RMSI SIB1, such that the SS/PBCH block and the RMSI SIB1 occupy the same time period.

[18] The start of the SS/PBCH block and the start of the RMSI SIB1 may be aligned.

[19] The SS/PBCH block and the RMSI SIB1 may be of equivalent length in time and terminate simultaneously.

[20] The PDCCH and PDSCH may be transmitted in series or in parallel.

[21] There is also provided a base station configured to perform the methods described herein.

[22] There is also provided a UE configured to decode an MIB transmitted in accordance the methods described herein.

## Brief description of the drawings

[23] Further details, aspects and embodiments of the invention will be described, by way of example only, with reference to the drawings. Elements in the figures are illustrated for simplicity and clarity and have not necessarily been drawn to scale. Like reference numerals have been included in the respective drawings to ease understanding.

[24] Figure 1 shows selected elements of a cellular communications network.

## Detailed description of the preferred embodiments

[25] Those skilled in the art will recognise and appreciate that the specifics of the examples described are merely illustrative of some embodiments and that the teachings set forth herein are applicable in a variety of alternative settings.

[26] Figure 1 shows a schematic diagram of three base stations (for example, eNB or gNBs depending on the particular cellular standard and terminology) forming a cellular network. Typically, each of the base stations will be deployed by one cellular network operator to provide geographic coverage for UEs in the area. The base stations form a Radio Area Network (RAN). Each base station provides wireless coverage for UEs in its area or cell. The base stations are interconnected via the X2 interface and are connected to the core network via the S1 interface. As will be appreciated only basic details are shown for the purposes of exemplifying the key features of a cellular network. A PC5 interface is provided between UEs for SideLink (SL) communications. The interface and component names mentioned in relation to Figure 1 are used for example only and different systems, operating to the same principles, may use different nomenclature.

[27] The base stations each comprise hardware and software to implement the RAN's functionality, including communications with the core network and other base stations, carriage of control and data signals between the core network and UEs, and maintaining wireless communications with UEs associated with each base station. The core network comprises hardware and software to implement the network functionality, such as overall network management and control, and routing of calls and data.

[28] The standards (section 7.4.3.1 of the 3GPP Technical Standard 38.211) defines the time-frequency structure of an SS/PBCH block. In the time domain, an SS/PBCH block consists of 4 OFDM symbols, numbered in increasing order from 0 to 3 within the SS/PBCH block

[29] In the frequency domain, an SS/PBCH block consists of 240 contiguous subcarriers (20 resource blocks each comprising of 12 sub-carriers) with the subcarriers numbered in increasing order from 0 to 239 within the SS/PBCH block.

[30] MIB carries system frame number (SFN), common sub-carrier spacing (SCS) (common SCS is the SCS used to decode SIB1), demodulation reference symbols (DMRS) and the necessary information for a UE to decode SIB1. It also provides the information whether the current cell is barred.

[31] The base station transmits physical downlink control channel (PDCCH) over a pre-configured region of the time frequency grid, known as control resource set (CORESET). A search space provides a configuration associated to a given CORESET and specifies symbols and physical resource blocks (PRBs) used by a UE to attempt PDCCH decoding. 5G NR defines common and UE specific search spaces.

[32] Type 0 common search space is used for PDCCH transmissions, which provide resource allocation for SIB1. This search space is indicated using MIB, carried over PBCH, and can also

be indicated using PDCCH-ConfigCommon structure. Type 0 common search space is mapped on the CORESET with identity 0 (CORESET#0). PDCCH used for SIB1 resource allocation is transmitted with its cyclic redundancy check (CRC) encoded using system information (SI) radio network temporary identifier (RNTI), which is a fixed parameter known to all devices. This PDCCH is transmitted using DCI format 1\_0.

[33] More precisely PBCH embedded in SS/PBCH block carries the following information elements (3GPP TS38.331 and 3GPP TS38.213):

- subCarrierSpacingCommon
- PDCCH-ConfigSIB1 - controlResourceSetZero
- PDCCH-ConfigSIB1 - searchSpaceZero

[34] subCarrierSpacingCommon provides the SCS used to transmit PDCCH carrying SIB1 allocation, which can be different from the SCS used to transmit SS/PBCH block. controlResourceSetZero information element provides a row index using a 4-bit indication within a CORESET configuration table. There are different CORESET configuration tables for each combination of (SCS\_SS/PBCH, SCS\_PDCCH). Once a UE has decoded SS/PBCH block, and having found the subCarrierSpacingCommon, it can use the row index pointing to the relevant CORESET configuration table for the SCS combination in use for SS/PBCH block and PDCCH for SIB1. For each of its constituent rows, CORESET configuration table provides number of PRBs, number of symbols, resource block offset with respect to the SS/PBCH block, and the multiplexing pattern of SS/PBCH block and the CORESET. 3GPP Technical Standard 38.213 contains more details.

[35] searchSpaceZero provides an index (4-bit indication) pointing to a specific row within a search space configuration table. 5G NR has specified multiple search space configuration tables, where each table is applicable to a given frequency range and a given multiplexing pattern of SS/PBCH block and CORESET. Search space configuration table provides localization of search space in the frame, slot and the number of search space sets per slot so that the UEs can determine the correct search space for their PDCCH decoding attempts. 3GPP Technical Standard 38.213 contains more details.

[36] The PDCCH scheduling SIB1 uses DCI format 1\_0 which provides the resource allocation and other parameters necessary to decode PDSCH carrying SIB1. DCI format 1\_0 carries a field Time domain resource assignment (TDRA). TDRA indication from the PDCCH and dmrs-TypeA-Position indication from MIB help to choose the appropriate row from TDRA table. Each row from this table provides the information of time resource using slot offset, starting symbol and the length of the scheduled resource for PDSCH which will carry SIB1 information.

[37] SIB1 provides base station selection information, system information scheduling information, serving base station configuration and other emergency related information elements. Serving base station configuration comprises of downlink config common, uplink config common. DL config common in turn provides information regarding DL frequency, DL bandwidth part (BWP) and configuration for paging and broadcast control channels. BWP configuration comprises of common configuration for PDCCH and PDSCH. UL configure common provides frequency information for UL, initial UL BWP. BWP UL provides information about RACH, PUCCH and PUSCH configuration.

[38] For example, standards such as the 3GPP has specified two frequency ranges, frequency range (FR) 1 and FR2. FR1 was originally supposed to be up to 6 GHz, but later extended to 7.125 GHz. FR2 was originally specified from 24.25 GHz to 52.6 GHz. Release-15 and Release-16 operation for 5G New Radio (NR) was specified for these frequency ranges. Release-17 aims

to extend FR2 operation, going up to 71 GHz. These extensions may go to 100 GHz or even beyond due to wide availability of spectrum at such higher carrier frequencies and the progress in antennas/RF that allow efficient communication at these frequencies which was previously deemed very difficult. Systems operating at such higher carrier frequencies will resort to beam based transmissions. These systems need to transmit SS/PBCH blocks, and the remaining minimum system information SIB1 or RMSI (scheduling command in the form of PDCCH and the information in PDSCH) in each beam direction with a given periodicity in a broadcast manner. For FR2, the base station may employ up to 64 beams. This incurs considerable overhead and imposes certain scheduling restrictions due to mandatory beam sweeps.

[39] For beam-based operation, the base station will transmit a SS/PBCH block, PDCCH in CORESET 0 and associated PDSCH carrying SIB1 in each beam direction. With large number of active beams, where the user density may not be equally distributed, transmission of SS/PBCH block, PDCCH and PDSCH for SIB1 require the activation of each beam for a minimum duration allowing such transmissions, resulting in waste of time-frequency resource leading to very poor system efficiency. The issue will become more serious with new combinations for SCS of SS/PBCH block and PDCCH scheduling SIB1. The issue is aggravated in case of unlicensed spectrum due to channel uncertainty, where a base station may lose the channel ownership in the gaps between any of these transmissions or due to the requirement of performing channel access procedures between these transmissions.

[40] The transmission of minimum system information describes methods of multiplexing between SS/PBCH block and CORESET 0. In addition, for optimized transmission of SS/PBCH block and SIB1 and resource allocations for PDSCH, which when combined with the described multiplexing patterns reduce the system overhead required to transmit such control information. The gap minimization schemes described herein provide protection against losing the channel ownership. This makes them attractive for operation over shared carriers. Additionally, the schemes described circumvent requirements to ensure channel access after a transmission gap. As a result, the methods described herein are suitable in unlicensed spectrum.

[41] CORESET configuration and PDSCH resource scheduling options ensure the transmission of PDCCH in CORESET0 and the scheduled PDSCH confined within the same time duration as of the SS/PBCH block. This leads to the minimum active time requirement in each single beam and minimizes the beam switching which introduces delays and transients. This uses comparatively larger frequency resource span, as different pieces of minimum system information are frequency multiplexed. This may though be quite acceptable at higher carrier frequencies where typically large bandwidths are available. This is suitable for operation over unlicensed shared carriers as it minimizes the requirements for channel sensing in different beams and also reduces the probability of channel ownership being lost to some other devices during the transmission of SS/PBCH block and RMSI. The individual pieces of system information are transmitted in the form of one inseparable cluster.

[42] The system transmits minimum system information of master information block (MIB) in a SS/PBCH block and the remaining minimum system information (RMSI), also called SIB1, with a shortest possible footprint in time. The SS/PBCH block uses fixed structure comprising of 4 OFDM symbols and transmits the RMSI (scheduling PDCCH and PDSCH) in full time overlap with SS/PBCH block despite their different sub-carrier spacings (SCS). This method uses combinations of SCS where the SCS of SS/PBCH block can be equal, 2x or 4x of the SCS of PDCCH scheduling RMSI. For these SCS combinations, precise CORESET 0, search space type 0 configurations (carrying PDCCH scheduling RMSI) and default data allocation entries for PDSCH are configured. These proposed configurations enable frequency multiplexing of SS/PBCH block with RMSI (PDCCH plus PDSCH), resulting in minimum time footprint for the

transmission of minimum system information, without any restriction on the used SCS. This results in significant overhead reduction for the transmission of system information. The three transmission units (SS/PBCH block, PDCCH and PDSCH of RMSI) are always transmitted as a single cluster, minimizing the impact of channel uncertainty.

[43] The RMSI is multiplexed into the same time footprint as the SS/PBCH block, so as to avoid the RMSI extending beyond the SS/PBCH block. This in turn reduces the overhead in each beam direction and provide decoding advantages as a result of the increased amount of RMSI data transmitted in the PDSCH.

[44] Each base station transmits a SS/PBCH block, allowing each UE to synchronize, and then transmit SIB1 (RMSI) scheduled through search space set 0 over CORESET#0. This provides the UEs with minimum system information necessary to decode downlink (DL) data or initiate uplink (UL) data transmission. This obliges the base stations to transmit SS/PBCH blocks, PDCCH transmitted over CORESET#0 scheduling SIB1 and SIB1 in all the beam directions as part of the basic cell coverage, enabling the UEs to bootstrap based upon this minimum system information.

[45] To minimize the overhead MIB/SIB1 transmission and avoid the channel uncertainty over shared carriers, SS/PBCH blocks, PDCCH and SIB1 (RMSI) need to be multiplexed in a smallest possible number of symbols. SS/PBCH block is a fixed set of signalling transmitted over 4 OFDM symbols (OS) with the sub-carrier spacing (SCS) of SS/PBCH block.

[46] As the SS/PBCH block and SIB1 (RMSI) use different sub-carrier spacing (SCS), a given multiplexing pattern may not necessarily be applicable to all combinations of SCS for SS/PBCH block and PDCCH scheduling RMSI.

[47] The method enables SIB1 transmission and multiplexing when a SS/PBCH block is using the SCS which is 4 times larger than the SCS of PDCCH scheduling PDSCH carrying SIB1. The 4 symbols carrying SS/PBCH block are equal to just one single symbol in the numerology of PDCCH of SIB1. This setting is applicable to {SS/PBCH block, PDCCH} SCS of {240, 60}, {480, 120}, {960, 240}, {1920, 480} KHz and other potential SCS combinations having similar ratio. The proposal for the multiplexing of CORESET 0 with SS/PBCH block and associated PDSCH carrying SIB1 (RMSI) is shown below. SS/PBCH block is transmitted over 4 OFDM symbols  $n$ ,  $n+1$ ,  $n+2$  and  $n+3$ . This is equivalent to one OFDM symbol 'm' in the numerology used by PDCCH in CORESET 0 and SIB1 PDSCH.

	n	n+1	n+2	N+3
	SS/PBCH Block (4 OS)			
CORESET 0 frequency span	PDCCH transmitted over a portion of Coreset 0 Configured Resource			
	RMSI PDSCH transmitted over a portion of Coreset 0 Configured Resource			
	m			

Table 1

[48] CORESET 0 is configured over one OFDM symbol which spans the same time duration as of the 4 OFDM symbols of the SS/PBCH block. In addition, PDCCH transmitted in CORESET 0 schedules PDSCH carrying SIB1 (RMSI) over a duration of 1 OFDM symbol which is also aligned with CORESET 0 and SS/PBCH block.

[49] The CORESET 0 configuration, search space Type 0 configuration and default PDSCH allocation table, so called time domain resource assignment (TDRA) table, need to be updated so that CORESET 0 configuration should support single symbol configuration with large enough PRBs. For this purpose, CORESET#0 configuration occupying 192 or more PRBs can be permitted. The relevant search space configuration table should add entries so that the first symbol index value is aligned with the first OFDM symbol of SS/PBCH block. Default TDRA table for PDSCH resource allocation supports the scheduling of PDSCH such that the starting OFDM symbol, denoted as S in TDRA tables, is aligned with the start of the CORESET0 and length of the allocated resource, denoted as L in TDRA tables, can be configured to be 1 OFDM symbol. As PDSCH is transmitted in the same slot as of the PDCCH in CORESET 0, the slot offset should be set to zero for this entry.

[50] The default active DL bandwidth part (BWP) is limited to the frequency span of the CORESET 0. This means that the UE is not expected to be scheduled outside of the frequency resource span indicated for CORESET 0. The base station can then update the active DL BWP through SIB1 signalling and requires the base station updates the active DL BWP to be greater than the CORESET 0 frequency span. To overcome this limitation, the system is configured for a CORESET 0 over a frequency span and to use a portion of configured CORESET 0 PRBs for transmission of PDCCH. This allows scheduling of PDSCH carrying RMSI over another portion of frequency resource span indicated for CORSET 0, by transmitting RMSI data over PDSCH scheduled in the resource configured for CORESET 0. Table 1 uses, as an illustration only, a PDCCH transmitted in CORESET 0 using 50% of the available CORESET 0 resource frequency span and the remaining 50% of the available CORESET 0 resource frequency span used for the RMSI PDSCH. One approach allows is that the whole frequency span of CORESET 0 can be indicated in PDCCH as the resource for PDSCH and the UE uses the decoded PDCCH to rate match around it. Another approach is to allocate precisely the frequency location of PDSCH within CORESET 0 using the frequency allocation field in PDCCH.

[51] The above example shows a SS/PBCH block, CORESET0 and RMSI PDSCH without any frequency gaps. This is by way of example only, and it will be appreciated that the actual configuration/scheduling may include frequency gap (PRBs) between blocks. The blocks span the same time duration despite the different SCSs, leading to the minimization of time duration used for the transmission of SS/PBCH block and RMSI. Similarly, the actual frequency resource span of CORESET 0, RMSI PDSCH can be higher or lower compared to SS/PBCH block, or split around the SS/PBCH block. This can be easily configured through resource block offset indication as part of CORESET 0 configuration.

[52] Alternatively, and in addition, an example of an RMSI transmission with an SS/PBCH block using the SCS which is twice the SCS of PDCCH scheduling PDSCH carrying SIB1 (RMSI) is illustrated in Table 2 below. The 4 OFDM symbols carrying SS/PBCH block are equal to two OFDM symbols in the numerology of PDCCH of SIB1. This setting is applicable to {SS/PBCH block, PDCCH} SCS of {120, 60}, {240, 120}, {480, 240}, {960, 480}, {1920, 960} KHz and other potential SCS combinations having this ratio.

[53] The two OFDM symbols in the numerology of PDCCH (in CORESET 0) are used both for CORESET 0 configuration and the scheduling of RMSI PDSCH in a frequency multiplexed manner with SS/PBCH block. This multiplexing method is shown in Table 2. This table shows SS/PBCH block spanning 4 OFDM symbol n, n+1, n+2 and n+3. The two equivalent OFDM symbols in the numerology of PDCCH, m and m+1, are used to configure CORESET 0 and to allocate resources for RMSI PDSCH scheduled through PDCCH transmitted in CORESET 0.

n	n+1	n+2	N+3
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	SS/PBCH Block (4 OS)	
CORESET 0 frequency span	PDCCH transmitted over a portion of Coreset 0 Configured Resource	
	RMSI PDSCH transmitted over a portion of Coreset 0 Configured Resource	
	m	m+1

Table 2

[54] This can be realized by supporting 2 OFDM symbols CORESET 0 configuration, with search space Type 0 configuration allowing it aligned with the first symbol of SS/PBCH block and by allowing 2 OFDM symbol PDSCH time domain resource allocation with the same start symbol as the start symbol of CORESET 0 aligned with the first OFDM symbol of SS/PBCH block.

[55] For operation with initial active DL BWP, which is confined to the CORESET 0 configured frequency resource span, RMSI PDSCH must be limited to this resource. Once the active DL BWP has been updated by the base station, RMSI PDSCH can be allocated within the DL BWP which is not necessarily confined within the CORESET 0 configured frequency resource span. In case the initial active DL BWP is restricted to CORESET 0 configured frequency resource span, PDCCH scheduling RMSI PDSCH can be transmitted over a portion of CORESET 0 configured resource and the remaining portion of the active DL BWP can be used to schedule RMSI PDSCH, as shown in Table 2.

[56] In this example, the scheduling command (PDCCH) and the data carrying MSI (PDSCH) are transmitted frequency multiplexed with SS/PBCH block, while being time domain multiplexed with each other. The 4 symbols of SS/PBCH block are equal to 2 OFDM symbols in the numerology of PDCCH. The two OFDM symbols in the numerology of PDCCH (in CORESET0) are equally split in time, allocating 1 OFDM symbol for CORESET 0 configuration and RMSI PDSCH is scheduled on the second OFDM symbol. This method thus has CORESET 0 configuration and RMSI PDSCH scheduling in a TDMA fashion with each other. CORESET 0 and SIB1 (RMSI) PDSCH jointly are frequency domain multiplexed with SS/PBCH block.

[57]

	n	n+1	n+2	N+3
	SS/PBCH Block (4 OS)			
CORESET 0 frequency span	PDCCH transmitted over a portion of Coreset 0 Configured Resource		RMSI PDSCH transmitted over full range of Coreset 0 Configured Resource	
	m		m+1	

Table 3

[58] Table 3 shows a CORESET0 configuration and RMSI PDSCH scheduling. The SS/PBCH block indicates 1 OFDM symbol CORESET 0 configuration and the PDCCH transmitted within

CORESET 0 schedules PDSCH (carrying RMSI) with a start symbol aligned with the last 2 OFDM symbols of SS/PBCH block and a length of 1 OFDM symbol. The CORESET configuration for {SS/PBCH block, PDCCH} SCS { $x$ ,  $x/2$ } KHz supports 1 OFDM symbol CORESET 0 configuration, the search space Type 0 needs to define a configuration with an entry such that it is aligned to the first OFDM symbol of the SS/PBCH block, and the default TDRA table has an entry with a PDSCH of length 1 OFDM symbol, starting at symbol  $m+1$ , aligned with the last 2 OFDM symbols of the SS/PBCH block. Thus CORESET 0 and PDSCH are multiplexed in time, and the frequency resource spans scheduled for PDSCH can be restricted within the CORESET 0 configured frequency resource spans and will lie within initial active DL BWP.

[59] CORESET 0 may be configured over a single OFDM symbol aligned with the first two OFDM symbols of SS/PBCH block, where SIB1 (RMSI) PDSCH is allocated to a time resource spanning two OFDM symbols aligned with the 4 OFDM symbols of SS/PBCH block and is illustrated in Table 4. Thus, CORESET 0 and PDSCH can be frequency multiplexed in the first OFDM symbol. This may be utilised when single symbol PDSCH is not deemed sufficient to carry SIB1 data. In this case, PDSCH can be allocated additional resources for better protection. In this example, PDCCH and PDSCH for RMSI are frequency multiplexed with SS/PBCH block, but time and frequency multiplexed with each other.

[60] For operation with initially active DL BWP, which is confined to the CORESET 0 configured frequency resource span, RMSI PDSCH must be limited to this same resource. The PDCCH is transmitted over a portion of CORESET 0 configured frequency span resource and the remaining portion of CORESET 0 configured frequency resource span can be used to transmit SIB1 PDSCH.

[61]

	n	n+1	n+2	N+3
	SS/PBCH Block (4 OS)			
CORESET 0 frequency span	PDCCH transmitted over a portion of Coreset 0 Configured Resource		RMSI PDSCH transmitted over full range of Coreset 0 Configured Resource	
	RMSI PDSCH transmitted over a portion of Coreset 0 Configured Resource			
	m		m+1	

Table 4

[62] A SS/PBCH block and a PDCCH over CORESET 0 scheduling PDSCH carrying RMSI having the same SCS is illustrated in Table 5. Four OFDM symbols in the numerology of PDCCH (in CORESET 0) are split such that 1 OFDM symbol is used for CORESET 0 configuration and 3 OFDM symbols are allocated to RMSI PDSCH. The SIB1 can contain a proportionally more information than that carried in the PDCCH transmitted in CORESET 0 and this provides proportionally more RMSI PDSCH resource. To adopt this multiplexing pattern, default time domain resource allocation in TDRA table needs to add new entries allowing scheduling of PDSCH over a length of 3 OFDM symbols, with a start symbol aligned to the 2<sup>nd</sup> OFDM symbol n+1 of SS/PBCH block.

	n	n+1	n+2	n+3
	SS/PBCH Block (4 OS)			
CORESET 0 frequency span	PDCCH transmitted over full range of Coreset 0 Configured Resource	RMSI PDSCH transmitted over full range of Coreset 0 Configured Resource		
	n	n+1	n+2	n+3

Table 5

[63] Where CORESET 0 and PDSCH are multiplexed in time, the frequency resource spans scheduled for PDSCH can be restricted within the CORESET 0 configured frequency resource spans and will lie within initial active DL BWP. This can be use when active DL BWP is restricted to the frequency resource span of the CORESET 0.

[64] A method where four OFDM symbols in the numerology of PDCCH (in CORESET0) are split such that 1 OFDM symbol is allocated for CORESET 0 configuration and all 4 OFDM symbols aligned with SS/PBCH block are allocated to RMSI PDSCH is illustrated in Table 6. This provides more resource allocation for SIB1 (RMSI) PDSCH compared to the previous example, and may improve the faster transmission of minimum system information. Table 5 shows the proposed design with 1 OFDM symbol CORESET 0 configuration and 4 OFDM symbols used for the scheduling of RMSI PDSCH.

	n	n+1	n+2	n+3
	SS/PBCH Block (4 OS)			
CORESET 0 frequency span	PDCCH transmitted over portion of Coreset 0 Configured Resource	RMSI PDSCH transmitted over full range of Coreset 0 Configured Resource		
	RMSI PDSCH transmitted over a portion of Coreset 0 Configured Resource			
	n	n+1	n+2	n+3

Table 6

[65] For active DL BWP restricted to CORESET 0 configuration, PDCCH is transmitted over a portion of CORESET 0 frequency resource span in the first OFDM symbol, and the remaining frequency resource span of DL BWP over the first symbol and the next 3 symbols are used for the transmission of SIB1 (RMSI) PDSCH.

[66] Although not shown in detail any of the devices or apparatus that form part of the network may include at least a processor, a storage unit and a communications interface, wherein the processor unit, storage unit, and communications interface are configured to perform the method of any aspect of the present invention. Further options and choices are described below.

[67] The signal processing functionality of the embodiments of the invention especially the gNB and the UE may be achieved using computing systems or architectures known to those who are skilled in the relevant art. Computing systems such as, a desktop, laptop or notebook computer, hand-held computing device (PDA, cell phone, palmtop, etc.), mainframe, server, client, or any other type of special or general purpose computing device as may be desirable or appropriate for a given application or environment can be used. The computing system can include one or more processors which can be implemented using a general or special-purpose processing engine such as, for example, a microprocessor, microcontroller or other control module.

[68] The computing system can also include a main memory, such as random access memory (RAM) or other dynamic memory, for storing information and instructions to be executed by a processor. Such a main memory also may be used for storing temporary variables or other intermediate information during execution of instructions to be executed by the processor. The computing system may likewise include a read only memory (ROM) or other static storage device for storing static information and instructions for a processor.

[69] The computing system may also include an information storage system which may include, for example, a media drive and a removable storage interface. The media drive may include a drive or other mechanism to support fixed or removable storage media, such as a hard disk drive, a floppy disk drive, a magnetic tape drive, an optical disk drive, a compact disc (CD) or digital video drive (DVD) (RTM) read or write drive (R or RW), or other removable or fixed media drive. Storage media may include, for example, a hard disk, floppy disk, magnetic tape, optical disk, CD or DVD, or other fixed or removable medium that is read by and written to by media drive. The

storage media may include a computer-readable storage medium having particular computer software or data stored therein.

[70] In alternative embodiments, an information storage system may include other similar components for allowing computer programs or other instructions or data to be loaded into the computing system. Such components may include, for example, a removable storage unit and an interface, such as a program cartridge and cartridge interface, a removable memory (for example, a flash memory or other removable memory module) and memory slot, and other removable storage units and interfaces that allow software and data to be transferred from the removable storage unit to computing system.

[71] The computing system can also include a communications interface. Such a communications interface can be used to allow software and data to be transferred between a computing system and external devices. Examples of communications interfaces can include a modem, a network interface (such as an Ethernet or other NIC card), a communications port (such as for example, a universal serial bus (USB) port), a PCMCIA slot and card, etc. Software and data transferred via a communications interface are in the form of signals which can be electronic, electromagnetic, and optical or other signals capable of being received by a communications interface medium.

[72] In this document, the terms 'computer program product', 'computer-readable medium' and the like may be used generally to refer to tangible media such as, for example, a memory, storage device, or storage unit. These and other forms of computer-readable media may store one or more instructions for use by the processor comprising the computer system to cause the processor to perform specified operations. Such instructions, generally referred to as 'computer program code' (which may be grouped in the form of computer programs or other groupings), when executed, enable the computing system to perform functions of embodiments of the present invention. Note that the code may directly cause a processor to perform specified operations, be compiled to do so, and/or be combined with other software, hardware, and/or firmware elements (e.g., libraries for performing standard functions) to do so.

[73] The non-transitory computer readable medium may comprise at least one from a group consisting of: a hard disk, a CD-ROM, an optical storage device, a magnetic storage device, a Read Only Memory, a Programmable Read Only Memory, an Erasable Programmable Read Only Memory, EPROM, an Electrically Erasable Programmable Read Only Memory and a Flash memory. In an embodiment where the elements are implemented using software, the software may be stored in a computer-readable medium and loaded into computing system using, for example, removable storage drive. A control module (in this example, software instructions or executable computer program code), when executed by the processor in the computer system, causes a processor to perform the functions of the invention as described herein.

[74] Furthermore, the inventive concept can be applied to any circuit for performing signal processing functionality within a network element. It is further envisaged that, for example, a semiconductor manufacturer may employ the inventive concept in a design of a stand-alone device, such as a microcontroller of a digital signal processor (DSP), or application-specific integrated circuit (ASIC) and/or any other sub-system element.

[75] It will be appreciated that, for clarity purposes, the above description has described embodiments of the invention with reference to a single processing logic. However, the inventive concept may equally be implemented by way of a plurality of different functional units and processors to provide the signal processing functionality. Thus, references to specific functional units are only to be seen as references to suitable means for providing the described functionality, rather than indicative of a strict logical or physical structure or organisation.

[76] Aspects of the invention may be implemented in any suitable form including hardware, software, firmware or any combination of these. The invention may optionally be implemented, at least partly, as computer software running on one or more data processors and/or digital signal processors or configurable module components such as FPGA devices.

[77] Thus, the elements and components of an embodiment of the invention may be physically, functionally and logically implemented in any suitable way. Indeed, the functionality may be implemented in a single unit, in a plurality of units or as part of other functional units. Although the present invention has been described in connection with some embodiments, it is not intended to be limited to the specific form set forth herein. Rather, the scope of the present invention is limited only by the accompanying claims. Additionally, although a feature may appear to be described in connection with particular embodiments, one skilled in the art would recognise that various features of the described embodiments may be combined in accordance with the invention. In the claims, the term 'comprising' does not exclude the presence of other elements or steps.

[78] Furthermore, although individually listed, a plurality of means, elements or method steps may be implemented by, for example, a single unit or processor. Additionally, although individual features may be included in different claims, these may possibly be advantageously combined, and the inclusion in different claims does not imply that a combination of features is not feasible and/or advantageous. Also, the inclusion of a feature in one category of claims does not imply a limitation to this category, but rather indicates that the feature is equally applicable to other claim categories, as appropriate.

[79] Furthermore, the order of features in the claims does not imply any specific order in which the features must be performed and in particular the order of individual steps in a method claim does not imply that the steps must be performed in this order. Rather, the steps may be performed in any suitable order. In addition, singular references do not exclude a plurality. Thus, references to 'a', 'an', 'first', 'second', etc. do not preclude a plurality.

[80] Although the present invention has been described in connection with some embodiments, it is not intended to be limited to the specific form set forth herein. Rather, the scope of the present invention is limited only by the accompanying claims. Additionally, although a feature may appear to be described in connection with particular embodiments, one skilled in the art would recognise that various features of the described embodiments may be combined in accordance with the invention. In the claims, the term 'comprising' or "including" does not exclude the presence of other elements.

## Claims

1. A method of transmitting minimum system information from a base station in an OFDM transmission system, the method comprising the steps of:  
transmitting an MIB in the form of a SS/PBCH block and RMSI information on at least one other channel ; wherein  
the transmitting step includes  
multiplexing the SS/PBCH with the RMSI information; and  
transmitting the RMSI information in the CORESET#0 frequency span.
2. The method of claim 1, wherein the RMSI information includes at least SIB1 RMSI PDCCH and/or PDSCH channel.
3. The method of claim 1, wherein the SS/PBCH block is transmitted over a number  $n$  of at least one OFDM symbol and the RMSI information is transmitted over a number  $m$  of at least one OFDM symbol, and wherein  $n$  is a multiple of  $m$ .
4. The method of claim 1, wherein the SS/PBCH block is transmitted over a number  $n$  of at least one OFDM symbol and the RMSI information is transmitted over a number  $m$  of at least one OFDM symbol, and wherein  $n$  is equal to  $m$ .
5. The method of any preceding claim wherein the multiplexing step comprises multiplexing in time.
6. The method of any preceding claim wherein the OFDM system operates in both licensed and unlicensed spectrum.
7. The method of any preceding claim wherein the SCS of the channel carrying the SS/PBCH block is a multiple of the SCS of the channel carrying the RMSI information, such that the SS/PBCH block and the RMSI information occupy the same time period.
8. The method of any preceding claim wherein the start of the SS/PBCH block and the start of the RMSI information are aligned.
9. The method of claim 8 wherein the SS/PBCH block and the RMSI information are of equivalent length in time and terminate simultaneously.
10. The method of any preceding claim wherein PDCCH and PDSCH are transmitted in series.
11. The method of any of claims 1 to 9 wherein PDCCH and PDSCH are transmitted in parallel.
12. A base station configured to perform the method of any of claims 1 to 11.
13. A UE configured to decode an MIB transmitted in accordance with any of claims 1 to 11.

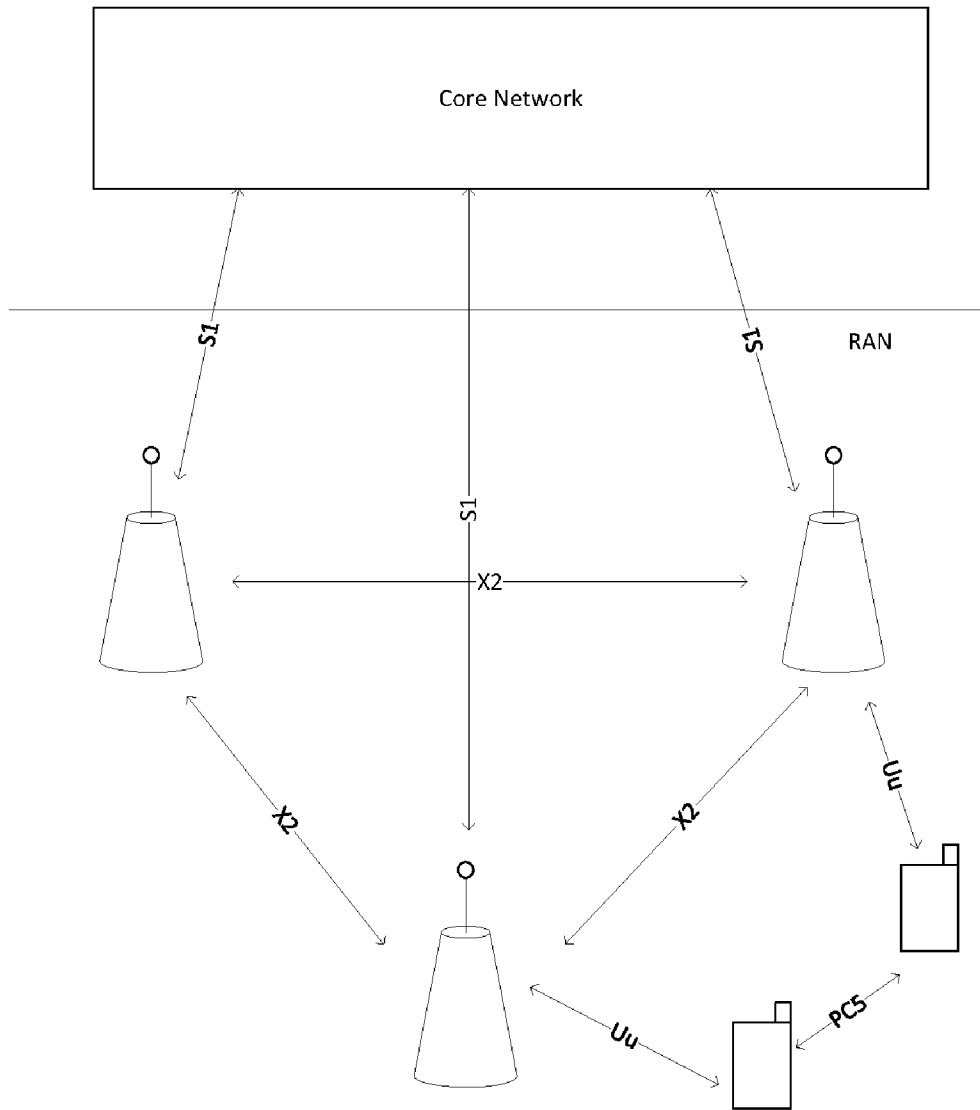


Figure 1

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2021/108261

<b>A. CLASSIFICATION OF SUBJECT MATTER</b> H04W 56/00(2009.01)i; H04B 17/382(2015.01)i  According to International Patent Classification (IPC) or to both national classification and IPC		
<b>B. FIELDS SEARCHED</b> Minimum documentation searched (classification system followed by classification symbols) H04W; H04B  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) CNPAT, WPI, EPODOC, CNKI, 3GPP: OFDM, MSI, SS+, PBCH, RMSI, multiplex, CORESET		
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 110971322 A (VIVO MOBILE COMMUNICATION CO., LTD.) 07 April 2020 (2020-04-07) description, paragraphs [0044]-[0136]	1-13
A	WO 2019050165 A1 (ELECTRONICS AND TELECOMMUNICATIONS RESEARCH INSTITUTE) 14 March 2019 (2019-03-14) the whole document	1-13
A	US 2018234931 A1 (QUALCOMM INCORPORATED) 16 August 2018 (2018-08-16) the whole document	1-13
A	HUAWEI et al. "NR Paging Options" 3GPP TSG-RAN WG2 #101bis R2-1805788, 20 April 2018 (2018-04-20), the whole document	1-13
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.		
<p>* Special categories of cited documents:</p> <p>“A” document defining the general state of the art which is not considered to be of particular relevance</p> <p>“E” earlier application or patent but published on or after the international filing date</p> <p>“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)</p> <p>“O” document referring to an oral disclosure, use, exhibition or other means</p> <p>“P” document published prior to the international filing date but later than the priority date claimed</p> <p>“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</p> <p>“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</p> <p>“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</p> <p>“&amp;” document member of the same patent family</p>		
Date of the actual completion of the international search <b>12 October 2021</b>		Date of mailing of the international search report <b>21 October 2021</b>
Name and mailing address of the ISA/CN <b>National Intellectual Property Administration, PRC 6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088 China</b> Facsimile No. (86-10)62019451		Authorized officer <b>ZHANG, Pan</b>  Telephone No. 86-(10)-53961577

**INTERNATIONAL SEARCH REPORT**  
**Information on patent family members**

International application No.

**PCT/CN2021/108261**

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