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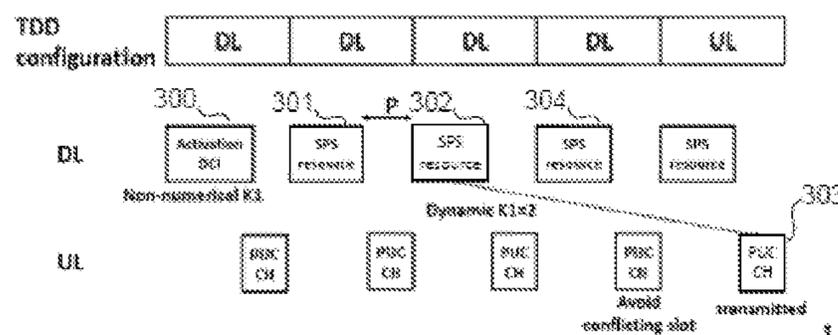


Figure 3

(57) Abstract: Methods for transmission of feedback relating to DL transmissions on periodic resources. A dynamic delay may be defined for the period between the transmission and feedback transmission. The delay may be specified with the DL transmission. Feedback transmissions may be delayed to a later available slot, or a flexible slot may be switched uplink for the feedback transmission.

Feedback for Periodic Resources

Technical Field

[1] The following disclosure relates to the transmission of feedback for DL messages carried on periodic resources.

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). 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, 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] A base station may configure DL semi-persistent scheduling (SPS) resources which occur periodically. DL SPS periodicity may be set as low as 0.5ms, which is equivalent to 1 slot with SCS of 30kHz, thus making them suitable for URLLC services. In DL SPS transmission, the base station configures different DL SPS configurations (which may be applicable to individual or groups of UEs) to UEs by radio resource control (RRC) and then transmits downlink control information (DCI) messaging to activate the desired DL SPS configurations. The UEs are thus aware of potential PDSCH locations such that a base station can transmit on PDSCH without an

associated PDCCH control message scheduling the particular transmission. This type of transmission reduces alignment time, transmission time and processing time of PDCCH as well as PDCCH blocking probability.

[9] For DL SPS transmission, a base station may configure at least some parameters using higher layer signalling (for example RRC). The base station then activates the DL SPS configuration using a DCI sent using a special identity, called SC-RNTI. Similar to DL dynamic transmissions, when the base station configures and activates the DL SPS resources by a DCI, the activation DCI contains PDSCH-to-HARQ-feedback indicator K1 indicating the number of slots from the end of PDSCH to the beginning of feedback on PUCCH. This parameter indicating the PDSCH-to-HARQ-feedback timing is then used throughout the active time of the relevant SPS configuration. If the UE receives PDSCH in slot n , the UE will transmit HARQ feedback in slot $n+K1$. However, in TDD configuration, if the slot $n+K1$ is a DL slot, the UE cannot transmit PUCCH carrying HARQ feedback in that slot and cancels PUCCH transmission following Release 15.

[10] With a periodicity of down to 0.5ms the rate of DL SPS may be high, but the value K1 is only indicated once at activation of DL SPS configuration. This is different from dynamic DL scheduling where the scheduling DCI will indicate the feedback timing for the scheduled transmission. In 5G, the network has extreme control over switching DL/UL configurations and dynamic switching using slot-based DCI are supported, such that the collision probability between the resources for HARQ feedback transmission and slot format in semi-static and dynamic TDD configuration increases. The situation is even more severe if the DL slots are configured frequently.

[11] When DL SPS configurations with short periodicities (e.g. down to 0.5 ms) are used for URLLC services/applications, the HARQ relevant conflicts can degrade URLLC QoS. In Figure 2, DL SPS resources are configured for a UE with a periodicity of P in TDD configuration. The K1 value indicated by the activation DCI is 3. A PDSCH is sent to the UE in the first SPS resources. Based on K1 equal to 3, HARQ feedback is expected to be transmitted in the fourth slot in Figure 2 that is 3 slots after the first slot containing SPS PDSCH. However, this slot is a DL slot and cannot be used for an UL transmission of HARQ feedback. Following Release 15, this HARQ feedback is dropped without being resumed to be transmitted in the next PUCCH.

[12] If the Release 15 mechanism is used and HARQ feedback is dropped due to UL/DL slot conflict as shown in Figure 2, the reliability of PDSCH degrades due to missing HARQ feedback (hence retransmission may not be carried out by the base station) and the specified QoS may not be achieved. The base station could automatically retransmit data without HARQ feedback, but this causes poor spectrum utilization due to unnecessary retransmissions when the UE decodes correctly the first TB but HARQ feedback is dropped due to TDD conflict.

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

Summary

[14] This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

[15] There is provided a method of feedback transmission from a UE to a base station in a cellular communications network for use with periodically occurring DL transmission resources, the method comprising transmitting a signal from a base station to at least one UE activating a configured SemiPersistent Scheduling (SPS) DL configuration for the at least one UE, the SPS-

DL configuration comprising a plurality of periodic occasions of SPS-DL transmission resources, and in an occasion of the SPS-DL transmission resources transmitting an indication of a delay period after which feedback related to that occasion should be transmitted by the UE to the base station.

[16] The indication of the delay period may be multiplexed with a DL data transmission in the occasion.

[17] The signal activating the SPS-DL configuration may include an indication that the delay period will be defined dynamically.

[18] The signal activating the SPS-DL configuration may include a default delay period.

[19] The default delay period may be utilised if no DL transmission is received at a UE in an occasion of the SPS-DL transmission resources, or if a delay period is not specified in an occasion.

[20] The delay period may only apply to the occasion in which it is received.

[21] The delay period may apply to a defined number of occasions of the SPS-DL transmission resources.

[22] The method may further comprise transmitting feedback from the UE to the base station after the delay period.

[23] An ACK-only HARQ protocol may be utilised.

[24] NACK feedback may only be sent if a DMRS power estimate for an occasion is above a threshold.

[25] The delay period may be indicated by an index to a pre-defined table of delay values.

[26] The pre-defined table of delay values may include an entry indicating to utilise a previously defined delay period.

[27] The base station may indicate to the at least one UE that a flexible slot is being defined as an UL slot for the transmission of feedback for at least one occasion of the SPS-DL resources.

[28] There is also provided a method of feedback transmission from a UE to a base station in a cellular communications network for use with periodically occurring DL transmission resources, the method performed at UE and comprising receiving a signal from a base station activating a configured SemiPersistent Scheduling (SPS) DL configuration for the UE, the SPS-DL configuration comprising a plurality of periodic occasions of SPS-DL transmission resources, and in an occasion of the SPS-DL transmission resources receiving an indication of a delay period after which feedback related to that occasion should be transmitted by the UE to the base station.

[29] The indication of the delay period may be multiplexed with a DL data transmission in the occasion.

[30] The signal activating the SPS-DL configuration may include an indication that the delay period will be defined dynamically.

[31] The signal activating the SPS-DL configuration may include a default delay period.

[32] The default delay period may be utilised if no DL transmission is received at a UE in an occasion of the SPS-DL transmission resources, or if a delay period is not specified in an occasion.

[33] The delay period may only apply to the occasion in which it is received.

[34] The delay period may apply to a defined number of occasions of the SPS-DL transmission resources.

[35] The method may further comprise transmitting feedback from the UE to the base station after the delay period.

[36] An ACK-only HARQ protocol may be utilised.

[37] NACK feedback may only be sent if a DMRS power estimate for an occasion is above a threshold.

[38] The delay period may be indicated by an index to a pre-defined table of delay values.

[39] The pre-defined table of delay values may include an entry indicating to utilise a previously defined delay period.

[40] The method may further comprise receiving from the base station an indication that a flexible slot is being defined as an UL slot for the transmission of feedback for at least one occasion of the SPS-DL resources.

[41] There is also provided a method of feedback transmission from a UE to a base station in a cellular communications network for use with periodically occurring DL transmission resources, the method comprising transmitting a signal from a base station to at least one UE activating a configured SemiPersistent Scheduling (SPS) DL configuration for the at least one UE, the SPS-DL configuration comprising plurality of periodic occasions of DL transmission resources, and transmitting an indication to the least one UE of a delay period after which feedback related to each occasion of the SPS-DL resources should be transmitted, and if the indicated delay period coincides with a downlink slot, the UE transmits feedback in a subsequently available uplink slot.

[42] A flexible slot subsequent to the delay period may be indicated for use as an UL slot for feedback transmission.

[43] The slot for feedback transmission may be indicated in a Slot Formation Indications (SFI).

[44] There is also provided a method of feedback transmission from a UE to a base station in a cellular communications network for use with periodically occurring DL transmission resources, the method comprising performed at a UE and comprising receiving a signal from a base station activating a configured SemiPersistent Scheduling (SPS) DL configuration for the UE, the SPS-DL configuration comprising plurality of periodic occasions of DL transmission resources, and receiving an indication of a delay period after which feedback related to each occasion of the SPS-DL resources should be transmitted, and if the indicated delay period coincides with a downlink slot, transmitting feedback in a subsequently available uplink slot.

[45] The method may further comprise receiving an indication that a flexible slot subsequent to the delay period is for use as an UL slot for feedback transmission.

[46] The slot for feedback transmission may be indicated in a Slot Formation Indications (SFI).

[47] There is provided a method of feedback transmission for use with periodically occurring DL transmission resources. At least one transmission in an occasion of the DL transmission resources includes an indication of a delay period after which feedback for that occasion should be transmitted. The delay period may be indicated by a value multiplexed with the DL transmission. When the periodic resources are activated an indication may be included that the delay period will be defined dynamically. A default delay period may be specified.

[48] If dynamic delay periods are activated a UE is configured to decode the delay period from each transmission received on the relevant periodic resources and transmit feedback at the appropriate slot based on that delay. ACK-only feedback may be utilised.

[49] A base station may indicate to a UE that a flexible slot is being defined as an UL slot for feedback for periodic resources. The UE may then utilise that slot for feedback transmission. The UE may utilise the slot for transmission of feedback that has been delayed due to a conflict with a DL slot for the originally indicated transmission time (for example, if dynamic delay configuration is not utilised).

[50] A base station may be configured to activate periodic resources with an indication that a feedback delay value will be defined in each occasion. The base station then includes such a delay value in each transmission on the relevant periodic resources.

[51] The disclosure also includes a UE and/or a base station configured to perform the relevant steps of the methods described herein.

Brief description of the drawings

[52] 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.

[53] Figure 1 shows a schematic diagram of selected elements of a cellular communications system;

[54] Figure 2 shows a feedback process with fixed delay;

[55] Figure 3 shows a feedback process with variable delay;

[56] Figure 4 shows a feedback process with feedback multiplexing; and

[57] Figure 5 shows a feedback process using flexible slots.

Detailed description of the preferred embodiments

[58] 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.

[59] 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.

[60] 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.

[61] The following disclosure provides mechanisms to ensure the transmission of HARQ feedback for DL SPS transmissions operating in TDD mode, thereby seeking to address the difficulty discussed above. As discussed below, transmission of HARQ feedback and PDSCH retransmission (if needed) for DL SPS transmissions are guaranteed, while also avoiding the unnecessary retransmission of PDSCH. There is also an aim to avoid increased the overhead in the activation DCI for SPS configurations and to bring flexibility to HARQ feedback transmission. Furthermore, there is an aim to reduce latency, improve resource utilization when the flexible slots are able to be used for HARQ feedback transmission postponed, and to reduce PUCCH overhead.

[62] As discussed above, a PDSCH-to-HARQ-feedback timing indicator is transmitted to a UE in an activation DCI for a DL SPS configuration transmitted from the base station. The bits in the PDSCH-to-HARQ feedback timing indicator specify an index in the table specified in RRC parameter: dl-DatatoUL-ACK in PUCCH-Config. Based on the index from the activation DCI, the UE knows the value of K1 in the table corresponding to that index. In DCI format 1_0, 3 bits in the

PDSCH-to-HARQ feedback timing indicator are mapped to K1 values from 1 to 8. In DCI format 1_1, there are from 0 to 3 bits used to indicate the row index of K1 from the mapping table. The number of bits is determined by $\log_2(I)$ where I is the number of elements (rows in the table) in the PUCCH-Config.dl-DatatoUL-ACK.

[63] Once DL SPS resources are activated by the base station, the value of K1 stays fixed throughout the SPS active time. The UE always transmits feedback K1 slots after a DL SPS PDSCH until the DL SPS resources are released by the base station. DL SPS PDSCH is transmitted without an associated PDCCH so the base station cannot change K1 at the time of PDSCH transmission. When the periodicity of DL SPS resources decreases to 1 slot of SCS of 30 kHz, there may be an increase of UL/DL slot conflict so feedback cannot be transmitted in the slot indicated by K1. Another drawback with a reduction of period is related to the high overhead of feedback. In Release 15, a UE will transmit NACK feedback in all occasions in which it does not decode a valid transport block, even if no transport block was transmitted in those resources (a base station may not use every occasion of periodic resources for transmission to a UE).

[64] To overcome such shortcomings in DL SPS feedback mechanisms, this disclosure proposes to indicate the SPS-PDSCH-to-feedback timing dynamically with each SPS transmission. That is, a K1 value may be indicated dynamically in each SPS transmission, which value is applicable only to that particular occasion of the periodic resources (or set of uses of the periodic resources). The activation DCI may include a default value which may then be overridden by a later specific value. Alternatively, no value may be specified or a particular indication given that the K1 value will be set on a per-occasion basis. For example, Table 1 shows an example table which contains a set of possible K1 values, and also a “no value” row. If the base station wishes to set a general value the timing indicator value is set corresponding to one of rows 0 – 6 (000 – 110) and the UE will then interpret the K1 value appropriately and apply that value for the relevant DL SPS resources. If the base station wishes to transmit a specific K1 value for each occasion, the activation DCI will include the value 111 in its field corresponding to non-numeric K1 value FFFF, which is interpreted by the UE to instruct it to wait for a specific K1 value for each occasion. The example of Table 1 is given for purposes of explanation only and as will be appreciated any desired set of rows, K1 values, and mappings may be utilised as required.

| Row index | PDSCH-to-HARQ feedback timing indicator | K1 value |
|-----------|---|----------|
| 0 | 000 | 1 |
| 1 | 001 | 2 |
| 2 | 010 | 3 |
| 3 | 011 | 4 |
| 4 | 100 | 5 |
| 5 | 101 | 6 |
| 6 | 110 | 7 |
| 7 | 111 | FFFF |

[65] Therefore, when a base station wishes to set K1 dynamically for each SPS occasion it may include an indication in the DCI message activating the SPS resources to indicate that the K1 value will be set on a per-occasion basis. For example, the table specified in dl-DatatoUL-ACK may contain an entry with a non-numeric value for K1 corresponding to the particular transmitted value included in the activation DCI as in the above example.

[66] For a DL SPS transmission there is no control transmission (DCI) on PDCCH before each occasion, and hence the K1 value to be utilised for a specific occasion may be included in the PDSCH transmission itself. For example, a set of bits (e.g. 0-3) in a defined location in PDSCH may indicate K1. Those bits are mapped to a K1 value in a table held by the UE, which may be the same table used when K1 is indicated in a DCI message. Thus, the SPS-PDSCH-to-feedback-timing indication (K1) is transmitted with the data on the PDSCH. The transmission

may use comparable techniques to the transmission of uplink control information over PUSCH. The SPS-PDSCH-to-feedback-timing indication can be punctured over known resource elements in the PDSCH transmission. The indicating bits are added to PDSCH after an equivalent number of bits in data of PDSCH is punctured. This method does not change the length of codeword in PDSCH so there is no confusion about code rate, or MCS between the base station and the UE. However, the PDSCH reliability decreases due to the additional data being carried.

[67] In summary some bits (e.g. 0-3) of data carried on PDSCH are punctured and replaced by bits to indicate the K1 value to be used for that particular DL SPS occasion.

[68] In the above example the K1 is only applicable to one occasion of DL SPS resources, but that value may persist for subsequent occasions. For example, the UE may continue to apply the specified value until a different value is received. This avoids the need to transmit K1 in every PDSCH, but rather a value may only be transmitted when the value changes.

[69] Figure 3 shows an example of the process described hereinbefore. After configuration of DL SPS resources, a DCI message 300 is transmitted to activate those resources. That DCI message 300 includes an indication that per-occasion K1 values will be set, for example by including a value which maps to a non-numerical K1 value in a table held by the UE. SPS resource 301 is not utilised for transmission to the UE, but SPS resource 302 is used. When making the transmission on resources 302 an indication of the K1 value to be utilised is carried on the PDSCH, for example by puncturing the data. In this example the transmitted value corresponds to a K1 of 2, and hence the HARQ feedback message 303 is transmitted 2 slots later, which is the next-available UL slot. When selecting a K1 value for a specific resource the base station may select the next-available UL slot based on TDD configuration to minimise latency of the feedback.

[70] If SPS resource occasion 304 is utilised and the base station selects the next available UL slot, the feedback will also be transmitted at occasion 303, thus requiring the feedback transmission to be multiplexed. Although such multiplexing is possible, if too many feedback messages are multiplexed the transmission may become unreliable. Figure 4 shows an example in which four SPS occasions occur before the next UL slot. For SPS PDSCH1 and SPS PDSCH2 K1 is set to a value of 4 & 3 respectively, such that the feedback for both occasions is transmitted in PUCCH1. Rather than selecting the next UL slot for feedback on SPS PDSCH 3 and SPS PDSCH 4, K1 is set to 3 & 2 respectively such that the feedback is sent at PUCCH2. The number of feedback messages in each UL slot is thus limited to 2 to mitigate degradation. The base station may select the number of feedback messages to multiplex into a slot depending on any appropriate parameters, for example, the size of PUCCH resources and the payload of the feedback. Other parameters such as channel quality could also be utilised. The base station may thus select K1 values based on feedback transmission parameters to balance latency and reliability.

[71] Slots may be defined as flexible, to allow dynamic definition as UL or DL. The base station is aware of flexible slots and may select such a slot for HARQ feedback (which it defines as UL) rather than waiting for the next statically defined UL slot, thereby reducing latency.

[72] Previously a UE is required to transmit HARQ feedback for every DL SPS occasion, even if no TB was transmitted in a particular occasion. However, this results in a high feedback overhead due to the transmission of negative feedback when in fact there was no transmission. A further drawback arises when K1 is specified dynamically since the UE does not have a K1 value for an occasion with no transmission. To mitigate the second drawback, a default K1 value may be defined to allow a feedback transmission if a PDSCH transmission is not received. This default value could also be used if the specific K1 value cannot be determined from the PDSCH transmission. However, this does not reduce the feedback overhead.

[73] To reduce the feedback overhead the UE may be configured to only transmit feedback if it determines that a PDSCH transmission was intended for the UE in a specific DL SPS occasion. If a TB is decoded successfully an ACK is sent, and if decode fails a NACK is sent, but only under permitted conditions. For example, NACK may be sent if DMRS power is estimated above a threshold since this is an indication that a message was transmitted to the UE. In an alternative arrangement ACK-only feedback may be utilised such that NACK messages are not used. That is, the UE transmits an ACK to the base station if the UE is able to decode a K1 value in the PDSCH and can decode the TB. In all other cases no feedback transmission is sent. The base station is aware of which occasions it has made a transmission in and the K1 values set for those transmissions it does make. The base station is thus aware when feedback should be received, and if no feedback is received at that time can assume the transmission failed and make a retransmission.

[74] The ACK-only method is summarised in Table 2 below.

| Case | UE behaviour | Base Station behaviour | Note |
|--|--------------------------|---|---|
| No TB transmitted | No feedback transmission | No action | No K1 value is dynamically indicated to the UE |
| TB transmitted but not decoded | No feedback transmission | Retransmit TB in periodically configured or dynamic resources (PDSCH associated with PDCCH) | K1 value is dynamically indicated to the UE in PDSCH but the base station does not receive any feedback. |
| TB transmitted and decoded correctly but ACK not decodable at the base station | ACK transmission | Retransmit TB in periodically configured or dynamic resources (PDSCH associated with PDCCH) | The UE transmits an ACK but the base station fails to decode, eg., due to bad channel conditions etc. Please note that base station will re-transmit but the UE will detect re-transmission due to NDI setting. |
| TB transmitted and decoded correctly | ACK transmission | No action | K1 value is dynamically indicated to the UE in PDSCH and is decoded correctly. This value is used to determine the UL slot for ACK transmission |

[75] The ACK-only feedback configuration may be utilised only when K1 is indicated dynamically. Activation of the dynamic K1 scheme may therefore also be interpreted by a UE as an indication to activate ACK-only feedback.

[76] In an alternative approach, a set value may be defined for the PDSCH-to-HARQ feedback timing (K1) as with the conventional approach, but if the resulting feedback time falls in a slot which is not an UL slot, the feedback is delayed instead of being dropped. Feedback may be delayed to the next UL slot, or the base station may indicate certain flexible slots that may be used as UL slots for HARQ feedback transmission if required by a UE. If a flexible slot is indicated for HARQ feedback transmission, only UEs whose PUCCH configuration gives a valid PUCCH occasion in the slot will use the slot for HARQ feedback. The indication of available flexible slots may be sent as common or group-common signalling, for example as part of a Slot Formation Indication (SFI). When an SFI is transmitted to a UE to update flexible slots to UL slots, it may include an indication whether those slots may be used for HARQ feedback, or not.

[77] This approach does not require the puncturing of bits in PDSCH and so reliability of PDSCH is not affected, but latency may be increased due to the delay of feedback to the next available flexible slot.

[78] Figure 5 shows an example in which $K1 = 2$ leading to the HARQ feedback transmission for SPS PDSCH1 and SPS PDSCH2 falling in DL slots. The UE buffers the feedback messages, and the base station transmits a DCI to the UE including an SFI to switch the next Flexible Slot to UL for HARQ feedback. The SFI may include a flag to indicate that the Flexible Slot is being switched to UL to carry the PUCCH (HARQ feedback) transmission (rather than for use by a PUSCH transmission). Accordingly, the UE transmits the feedback for both SPS occasions in that slot. The flag indicating use for PUCCH may trigger the UE to transmit all buffered HARQ feedback messages.

[79] In a modification of Figure 5, if the SFI indicates the flexible slot is being switched to UL, but for PUSCH (rather than PUCCH), and the UE is scheduled to transmit data the UE may multiplex the HARQ feedback message in the UCI with its scheduled PUSCH transmission. The UE may be configured to only perform this if PUSCH reliability will not be affected (for example the HARQ feedback size is below a threshold). As discussed above, an ACK-only feedback scheme may be utilised to reduce the number of feedback messages.

[80] CBG-based feedback may improve DL resource consumption since it allows only failed CBGs to be retransmitted, rather than retransmitting the whole TB. However, CBG-feedback will utilise more UL resources. The UE may be configured to use CBG feedback if there are sufficient resources to transmit it without degrading other signals, but otherwise to utilise TB-based feedback.

[81] As discussed with previous scheme, the transmission of feedback for every SPS occasion results in a significant resource overhead, the current scheme is also better utilized as ACK only scheme. Thus, when a UE successfully decodes a transport block, it transmits an ACK on the indicated occasion (or postpones it to a suitable slot in case of conflict). Otherwise, the UE does not transmit anything.

[82] As will be appreciated, parts or all, of the various examples may be utilised in combination. For example, ACK-only feedback may be used with any of the processes, or a default $K1$ value may be adopted for any of the processes.

[83] Specific aspects of the above disclosure are:-

- Dynamic indication of PDSCH-to-feedback timing. $K1$ is dynamically indicated by some bits in DL SPS PDSCH.
- Use of a non-numerical $K1$ value in the activation DCI of DL SPS configuration to inform the UE the utilization of dynamic- $K1$ -indication and ACK-only scheme.
- $K1$ is dynamically indicated by some bits in DL SPS PDSCH.
- Combination of dynamic- $K1$ -indication scheme and ACK-only scheme to guarantee the transmission of feedback in the UL/DL slot conflict in TDD configuration.
- Postponing the feedback in case of DL/UL conflict and enabling the use of flexible slots for feedback with common indication.
- Use SFI as a triggering signal to transmit the HARQ feedback postponed in dynamic TDD configuration.
- In case a UE is configured with PUSCH in flexible slot, enable the multiplexing of the postponed HARQ feedback with PUSCH.

[84] 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.

[85] 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.

[86] 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.

[87] 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) 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.

[88] 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.

[89] 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.

[90] 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.

[91] 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.

[92] 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.

[93] 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.

[94] 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.

[95] 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.

[96] 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.

[97] 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.

[98] 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 feedback transmission from a UE to a base station in a cellular communications network for use with periodically occurring DL transmission resources, the method performed by a base station and comprising the steps of:-
transmitting a signal to at least one UE activating a configured SemiPersistent Scheduling (SPS) DL configuration for the at least one UE, the SPS-DL configuration comprising a plurality of periodic occasions of SPS-DL transmission resources, and
in an occasion of the SPS-DL transmission resources transmitting an indication of a delay period after which feedback related to that occasion should be transmitted by the UE to the base station.
2. A method according to claim 1, wherein the indication of the delay period is multiplexed with a DL data transmission in the occasion.
3. A method according to any preceding claim, wherein the signal activating the SPS-DL configuration includes an indication that the delay period will be defined dynamically.
4. A method according to any preceding claim wherein the signal activating the SPS-DL configuration includes a default delay period.
5. A method according to claim 4, wherein the default delay period is utilised if no DL transmission is received at a UE in an occasion of the SPS-DL transmission resources, or if a delay period is not specified in an occasion.
6. A method according to any preceding claim, wherein the delay period only applies to the occasion in which it is received.
7. A method according to any of claims 1 to 5, wherein the delay period applies to a defined number of occasions of the SPS-DL transmission resources.
8. A method according to any preceding claim, further comprising transmitting feedback from the UE to the base station after the delay period.
9. A method according to any preceding claim, wherein an ACK-only HARQ protocol is utilised.
10. A method according to any of claims 1 to 8, wherein NACK feedback is only sent if a DMRS power estimate for an occasion is above a threshold.
11. A method according to any preceding claim, wherein the delay period is indicated by an index to a pre-defined table of delay values.
12. A method according to claim 11, wherein the pre-defined table of delay values includes an entry indicating to utilise a previously defined delay period.
13. A method according to any preceding claim, wherein the base station indicates to the at least one UE that a flexible slot is being defined as an UL slot for the transmission of feedback for at least one occasion of the SPS-DL resources.
14. A base station configured to perform the method of any of claims 1 to 13.
15. A method of feedback transmission from a UE to a base station in a cellular communications network for use with periodically occurring DL transmission resources, the method performed at UE and comprising

receiving a signal from a base station activating a configured SemiPersistent Scheduling (SPS) DL configuration for the UE, the SPS-DL configuration comprising a plurality of periodic occasions of SPS-DL transmission resources, and

in an occasion of the SPS-DL transmission resources receiving an indication of a delay period after which feedback related to that occasion should be transmitted by the UE to the base station.

16. A method according to claim 15, wherein the indication of the delay period is multiplexed with a DL data transmission in the occasion.
17. A method according to claim 15 or claim 16, wherein the signal activating the SPS-DL configuration includes an indication that the delay period will be defined dynamically.
18. A method according to any of claims 15 to 17, wherein the signal activating the SPS-DL configuration includes a default delay period.
19. A method according to claim 18, wherein the default delay period is utilised if no DL transmission is received at a UE in an occasion of the SPS-DL transmission resources, or if a delay period is not specified in an occasion.
20. A method according to any of claims 15 to 19, wherein the delay period only applies to the occasion in which it is received.
21. A method according to any of claims 15 to 20, wherein the delay period applies to a defined number of occasions of the SPS-DL transmission resources.
22. A method according to any of claims 15 to 21, further comprising transmitting feedback from the UE to the base station after the delay period.
23. A method according to any of claims 15 to 22, wherein an ACK-only HARQ protocol is utilised.
24. A method according to any of claims 15 to 22, wherein NACK feedback is only sent if a DMRS power estimate for an occasion is above a threshold.
25. A method according to any of claims 15 to 24, wherein the delay period is indicated by an index to a pre-defined table of delay values.
26. A method according to claim 25, wherein the pre-defined table of delay values includes an entry indicating to utilise a previously defined delay period.
27. A method according to any of claims 15 to 26, further comprising receiving from the base station an indication that a flexible slot is being defined as an UL slot for the transmission of feedback for at least one occasion of the SPS-DL resources.
28. A UE configured to perform the method of any of claims 15 to 27.
29. A method of feedback transmission from a UE to a base station in a cellular communications network for use with periodically occurring DL transmission resources, the method comprising
 - transmitting a signal from a base station to at least one UE activating a configured SemiPersistent Scheduling (SPS) DL configuration for the at least one UE, the SPS-DL configuration comprising plurality of periodic occasions of DL transmission resources, and
 - transmitting an indication to the least one UE of a delay period after which feedback related to each occasion of the SPS-DL resources should be transmitted, and

if the indicated delay period coincides with a downlink slot, the UE transmits feedback in a subsequently available uplink slot.

30. A method according to claim 29, wherein a flexible slot subsequent to the delay period is indicated for use as an UL slot for feedback transmission.
31. method according to claim 30, wherein the slot for feedback transmission is indicated in a Slot Formation Indications (SFI).
32. A method of feedback transmission from a UE to a base station in a cellular communications network for use with periodically occurring DL transmission resources, the method comprising performed at a UE and comprising
 - receiving a signal from a base station activating a configured SemiPersistent Scheduling (SPS) DL configuration for the UE, the SPS-DL configuration comprising plurality of periodic occasions of DL transmission resources, and
 - receiving an indication of a delay period after which feedback related to each occasion of the SPS-DL resources should be transmitted, and
 - if the indicated delay period coincides with a downlink slot, transmitting feedback in a subsequently available uplink slot.
33. A method according to claim 32, further comprising receiving an indication that a flexible slot subsequent to the delay period is for use as an UL slot for feedback transmission.
34. A method according to claim 33, wherein the slot for feedback transmission is indicated in a Slot Formation Indications (SFI).
35. A UE configured to perform the method of any of claims 32 to 34.

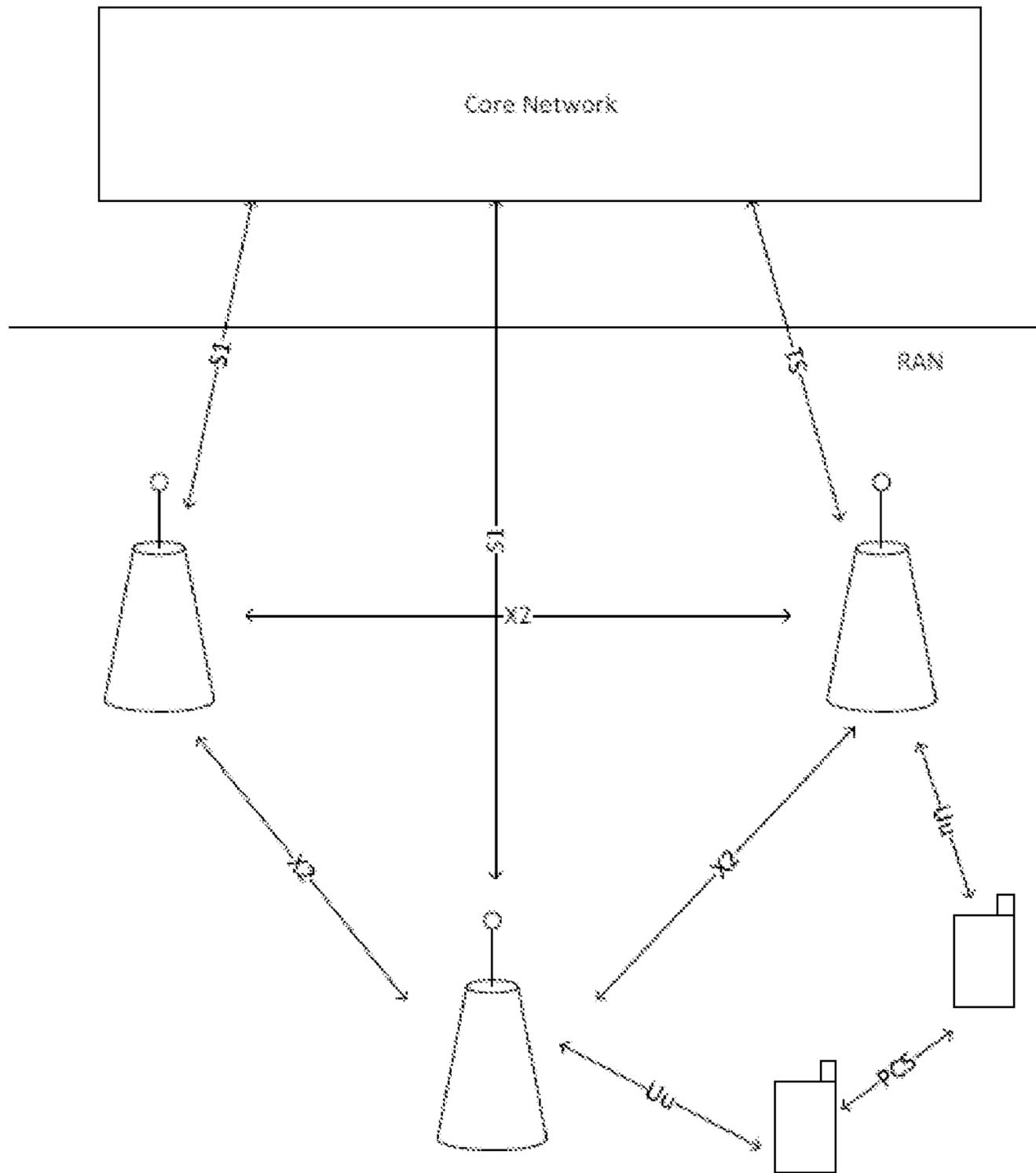


Figure 1

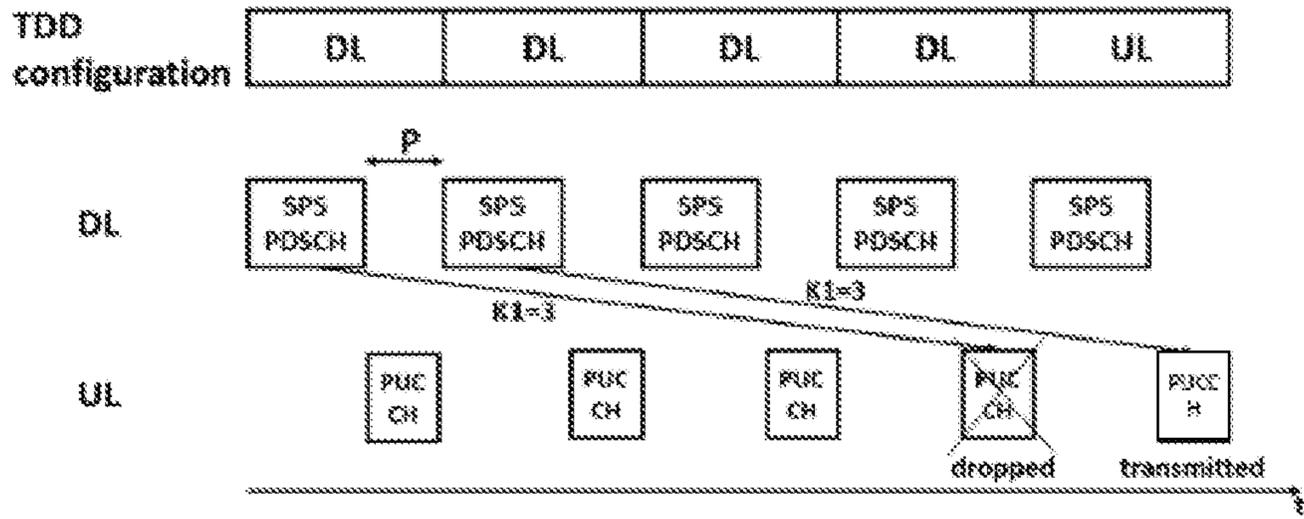


Figure 2

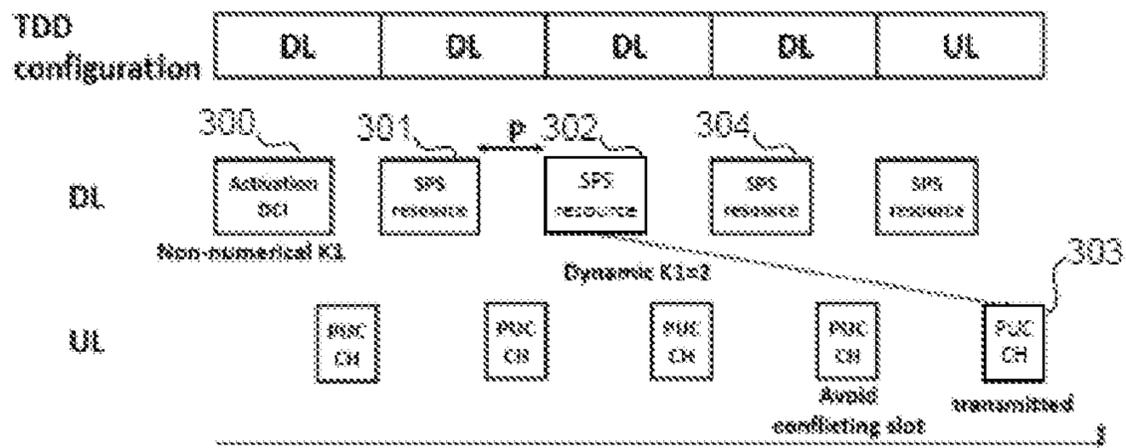


Figure 3

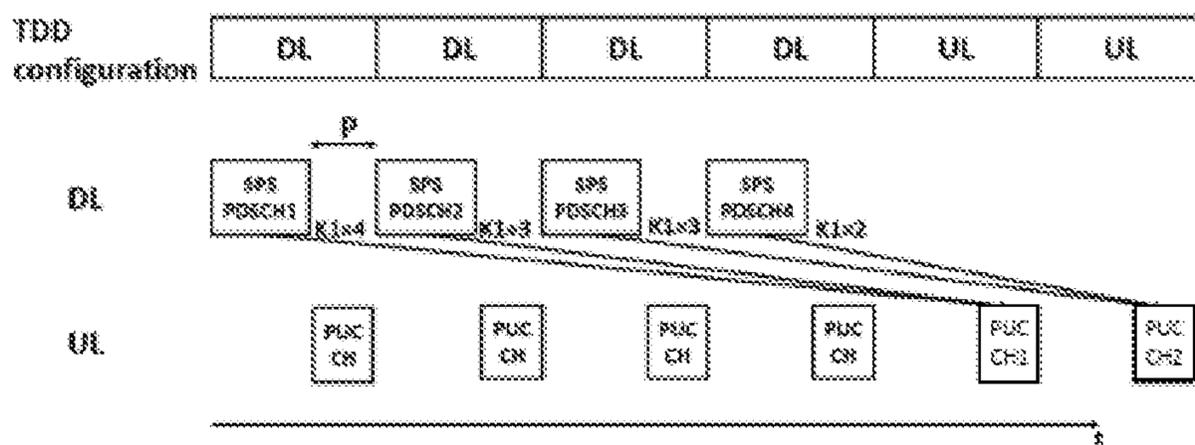


Figure 4

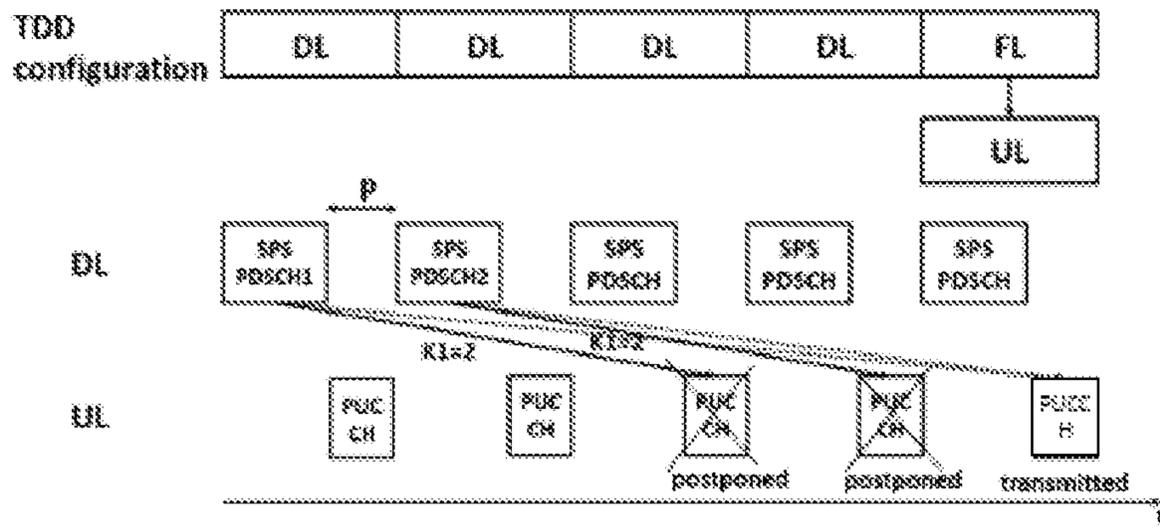


Figure 5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2020/129759

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| A. CLASSIFICATION OF SUBJECT MATTER H04L 1/18(2006.01)i; H04W 72/04(2009.01)i According to International Patent Classification (IPC) or to both national classification and IPC | | |
| B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) H04W; 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) EPTXT;USTXT;VEN;WOTXT;CNTXT;CNABS;3GPP;CNKI:indicat+, occasion, dynamically, sps, feedback, k value, dl, timing, ack, transmission, harq?ack, k1, conflict, dynamic+, delay, transmi+, sps?dl | | |
| C. DOCUMENTS CONSIDERED TO BE RELEVANT | | |
| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
| X | US 2019159251 A1 (ZTE CORP) 23 May 2019 (2019-05-23) description, paragraphs [0004], [0162] to [0167] | 1-35 |
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| <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>“&” document member of the same patent family</p> | | |
| Date of the actual completion of the international search 27 January 2021 | | Date of mailing of the international search report 07 February 2021 |
| Name and mailing address of the ISA/CN National Intellectual Property Administration, PRC 6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088 China Facsimile No. (86-10)62019451 | | Authorized officer WANG,Ran Telephone No. 86-(010)-62089401 |

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2020/129759

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