



(51) International Patent Classification:

H04W 72/04 (2009.01) H04W 76/14 (2018.01)

(21) International Application Number:

PCT/CN2021/121851

(22) International Filing Date:

29 September 2021 (29.09.2021)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

63/090,073 09 October 2020 (09.10.2020) US

(71) Applicant: HUIZHOU TCL CLOUD INTERNET CORPORATION TECHNOLOGY CO., LTD.

[CN/CN]; 5-6,11-14/F, TCL Science and Technology Building, 17 Huifeng 3rd Road, Zhongkai High-Tech Zone, Huizhou, Guangdong 516006 (CN).

(72) Inventors: GARCIA, Virgile; 5-6,11-14/F, TCL Science and Technology Building, 17 Huifeng 3rd Road, Zhongkai High-Tech Zone, Huizhou, Guangdong 516006 (CN).

SALIM, Umer; 5-6,11-14/F, TCL Science and Technology Building, 17 Huifeng 3rd Road, Zhongkai High-Tech Zone, Huizhou, Guangdong 516006 (CN).

(74) Agent: CHINA WISPRO INTELLECTUAL PROPERTY LLP.; Room A806, Zhongdi Building, China University of Geosciences Base, No. 8 Yuexing 3rd Road, High-Tech Industrial Estate, Nanshan District, Shenzhen, Guangdong 518057 (CN).

(81) Designated States (unless otherwise indicated, for every kind of national protection available):

AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,

HR, HU, ID, IL, IN, IR, IS, IT, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available):

ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))

Published:

— with international search report (Art. 21(3))

(54) Title: REDUCING POWER CONSUMPTION IN DIRECT WIRELESS COMMUNICATIONS SYSTEMS

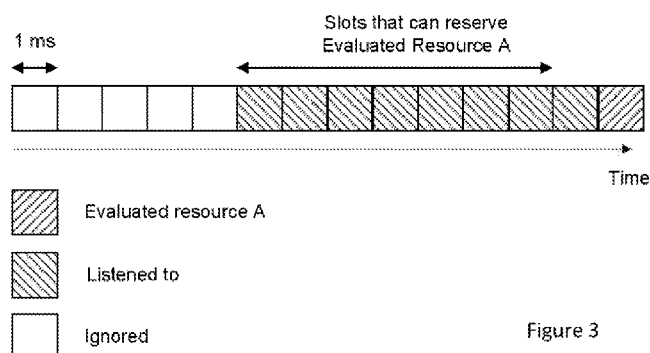


Figure 3

(57) **Abstract:** A power saving resource pool is defined for sidelink transmissions by power saving UEs. The power saving resource pool defines a subset of slots which the power saving UE may utilise to transmit or receive in. The power saving resource pool may be shared between UEs such that only relevant slots are utilised, and need to be monitored.



Reducing Power Consumption in Direct Wireless Communications Systems

Technical Field

[1] The following disclosure relates to point-to-point communications in a wireless communications system, and more particularly for energy saving procedures in partial sensing sidelink communications.

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

Summary

There is provided a method of sidelink communication between at least two UEs in a cellular communications network, the method comprising defining a power saving resource pool for use by power saving UEs; transmitting an indication of the transmission resources in the power saving resource pool from a base station to at least the at least two UEs; and when communicating to, or transmitting from, a power saving UE utilising only transmission resources of the power saving resource pool.

The power saving resource pool may be defined as a subset of a resource pool defined for use by the at least two UEs.

The power saving resource pool may be defined as a sub set of slots within the resource pool.

The indication of the transmission resources in the power saving resource pool may be sent utilising RRC signalling.

Prior to transmission a power saving UE may monitor only slots in the power saving resource pool.

A UE utilising the power saving resource pool may transmit an indication to other UEs of resources in the power saving resource pool.

The power saving resource pool may be defined by a UE utilising that resource pool.

The power saving resource pool may be defined by a base station.

Brief description of the drawings

[9] 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.

[10] Figure 1 shows selected elements of a cellular communications network;

[11] Figure 2 shows selected elements in a Radio Area Network of the cellular wireless communication network of Figure 1; and

[12] Figures 3 to 8 show timing of slots that are sensed to evaluate a potential resource for selection.

Detailed description of the preferred embodiments

[13] 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.

[14] 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.

[15] 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.

[16] In vehicle-to-vehicle (V2V) applications, the UEs may be incorporated into vehicles such as cars, trucks and buses. These vehicular UEs are capable of communicating with each other in in-coverage mode, where a base station manages and allocates the resources and in out-of-coverage mode, without any base station managing and allocating the resources. In vehicle-to-everything (V2X) applications, the vehicles may be communicating not only with other vehicles, but also with infrastructure, pedestrians, cellular networks and potentially other surrounding devices. V2X use cases include:

[17] Vehicles Platooning - this enables the vehicles to dynamically form a platoon travelling together. All the vehicles in the platoon obtain information from the leading vehicle to manage this platoon. This information allows the vehicles to drive closer than normal in a coordinated manner, going to the same direction and travelling together.

[18] Extended Sensors - this enables the exchange of raw or processed data gathered through local sensors or live video images among vehicles, road site units, devices of pedestrian and V2X application servers. The vehicles can increase the perception of their environment beyond of what their own sensors can detect and have a more broad and holistic view of the local situation. High data rate is one of the key characteristics.

[19] Advanced Driving - this enables semi-automated or full-automated driving. Each vehicle and/or RSU shares its own perception data obtained from its local sensors with vehicles in proximity and that allows vehicles to synchronize and coordinate their trajectories or manoeuvres. Each vehicle shares its driving intention with vehicles in proximity too.

[20] Remote Driving - this enables a remote driver or a V2X application to operate a remote vehicle for those passengers who cannot drive by themselves or remote vehicles located in dangerous environments. For a case where variation is limited and routes are predictable, such as public transportation, driving based on cloud computing can be used. High reliability and low latency are the main requirements.

[21] Figure 2 illustrates a base station 102 forming a RAN, and a transmitter (Tx) UE 150 and a receiver (Rx) UE 152 in the RAN. The base station 102 is arranged to wirelessly communicate over respective connections 154 with each of the Tx UE 150, i.e. UE-A, and the Rx UE 152, i.e. UE-B. The Tx UE 150 and the Rx UE 152 are arranged to wirelessly communicate with each other over a sidelink 156.

[22] Sidelink transmissions utilise TDD (half duplex) on either a dedicated carrier, or a shared carrier with conventional Uu transmissions between a base station and UE. Resource pools of transmission resources are utilised to manage resource and allocation and manage interference between potentially concurrent transmissions. A resource pool is a set of time-frequency resources from which resources for a transmission can be selected. UEs can be configured with multiple transmit and receive resource pools.

[23] Two modes of operation are used for resource allocation for sidelink communication depending on whether the UEs are within coverage of a cellular network. In Mode 1, the V2X communication is operating in-coverage of the base stations (eg eNBs or gNBs). All the scheduling and the resource assignments may be made by the base stations.

[24] Mode 2 applies when the V2X services operate out-of-coverage of cellular base stations. Here the UEs need to schedule themselves. For fair utilization, sensing-based resource allocation is generally adopted at the UEs. In Mode 2, UEs reserve resources for a transmission by transmitting a Sidelink Control Information (SCI) message indicating the resources to be used. The SCI notifies the recipient (which may be a single UE in unicast, a group of UEs in groupcast, or all reachable UEs in broadcast) of the details of the transmission it can expect. The SCI is the control information needed to decode the Sidelink data content, and also resource indications for reservations, with the first stage SCI being transmitted in the PSCCH and the second stage SCI being transmitted in the PSSCH. UEs may reserve transmission resources both for a first transmission of a Transport Block (TB) of data, and also for transmitting repetitions of the TB to improve reliability if the initial transmission fails.

[25] The standards, such as 3GPP TR 37.985, v16.0.0, describes the features required by to LTE and NR standards to support V2X services and a set of requirements sufficient for basic road safety services. Vehicles containing UEs with these features can use the uplink, downlink and sidelink to exchange information on their own status, such as position, speed, and heading with other nearby vehicles, infrastructure nodes, and pedestrians. The sidelink communications enhance efficiency and include sidelink carrier aggregation, higher-order modulation, and reduced latency.

[26] The apparatus, methods and systems described herein reduces power consumption of devices in sidelink autonomous resource selection mode. The (sub)set of slots to be sensed are configured and matched the configuration of the resource pool. This is achieved by monitoring retransmission resource reservations and periodic resource reservations. Also described herein is a further apparatus, methods and systems for power reduction by enabling down-selection of the sensing performed and configuring the sensing to match user capabilities.

[27] In particular, the apparatus, methods and systems described herein focuses on the power consumption part and improvements made over partial sensing defined by the standards.

[28] In the LTE standards, to avoid full sensing of the resource pools by the UE, and thus reduce power consumption, UEs can have limited or no sensing capabilities. When no sensing is made by UE, the UE simply performs a random selection, with the risk of collisions. A tradeoff method called "partial sensing" allows the UEs to sense the resource pool for a limited time to search for reservations that could impact their selection. The reservations are periodic and the possible periodicities are multiples of 100ms. In normal operation of partial sensing for resource selection, the partial sensing UE may choose any resource in the selection window. If n is the time of resource selection, the selection window is $[n+T1, n+T2]$. To determine whether the resources in the selection window are reserved or not, the partial sensing UE must sense the channel for potential transmissions with reservations that could fall in the selection window.

[29] Figure 3 shows the slots (8 1ms sensing slots only are shown for clarity) that need to be sensed in order to determine if the desired Slot A is free. In this example the limited sensing UE senses all previous (logical) slots to search for reservation of retransmissions.

[30] Partial sensing, is defined and allowed by the Radio Resource Control (RRC or higher layers) configurations. If partial sensing is configured by the higher layers, then the following two steps are used:

[31] Step 1) A candidate single-subframe resource for PSSCH transmission $R_{x,y}$ is defined as a set of L_{subCH} contiguous sub-channels with sub-channel $x+j$ in subframe t_y^{SL} where $j=0, \dots, L_{\text{subCH}}-1$. The UE determines by its implementation a set of subframes which consists of at least Y subframes within the time interval $[n+T_1, n+T_2]$ where selections of T_1 and T_2 are up to UE implementations under $T_1 \leq 4$ and $T_{2\min}(\text{prio}_{TX}) \leq T_2 \leq 100$, if $T_{2\min}(\text{prio}_{TX})$ is provided by higher layers for prio_{TX} , otherwise $20 \leq T_2 \leq 100$. Y is set in the RRC, n is the time of the resource selection, $n+T_1$ is the beginning of the selection window and $n+T_2$ is the end of the selection window. UE selection of T_2 fulfils the latency requirement and Y is greater than or equal to the high layer parameter *minNumCandidateSF*. The UE assumes that any set of L_{subCH} contiguous sub-channels included in the corresponding PSSCH resource pool (described in TS 36.213 g20 section 14.1.5) within the determined set of subframes corresponds to one candidate single-subframe resource. The total number of the candidate single-subframe resources is denoted by M_{total} .

[32] Step 2) If a subframe t_y^{SL} is included in the set of subframes in Step 1, the UE shall monitor any subframe $t_{y-k \times P_{\text{step}}}^{SL}$ if k -th bit of the high layer parameter *gapCandidateSensing* is set to 1. The UE shall perform the behaviour in the following steps based on PSSCH decoded and S-RSSI measured in these subframes. t_y is the time of the resource selected and P_{step} is 100ms in LTE.

[33] In LTE, periodicities are selected from a list of standardized values. When partial sensing UEs are configured in a resource pool, the possible values for periodicities are a multiple of 100ms, up to 1000ms. It is also possible to select which periodicities are allowed in a pool, configured by *ResourceReservePeriods* as a subset of the possible multiples of 100ms.

[34] For partial sensing UEs, only a part of the resources of the selection window are considered (the Y resources). Thus, for a particular resource in the selection window (at time t_Y), it is sufficient to check $t_Y - k \times P_{\text{step}}$, and where $P_{\text{step}} = 100\text{ms}$ meaning that the partial sensing UE checks every 100ms, which are the only possible place where an existing reservation by another UE falling at the desired time could be located. Thus, partial sensing allows the partial sensing UE to evaluate the at least Y resources (the resources configured in the resource pool) in the selection window.

[35] In particular, partial sensing is configured in absolute time with the *gapCandidateSensing* parameter. This parameter is a list of 10 Booleans, where the k^{th} value tells partial sensing UE whether or not to sense the time $k \times 100\text{ms}$ before the evaluated resource.

[36] If only part of the period values is allowed, the actual sensing needed is reduced since only these periods could lead to a reservation. However, the two lists are independently configured, and this leaves full flexibility in period configuration and partial sensing and it is up to the configuration to trade off the three aspects: possible periods; sensing power reduction; collision risk. Collision risks happen when partial sensing UE are not required to sense in the time that match configured periods, to reduce their power consumption.

[37] Resource pools may be configured to support periodic reservations, which can be configured up to 1000ms in advance, and can lead to collision if not sensed properly. When

configured to support periodic reservations the resource pool has a sensing window that starts up to 1100ms before the time of resource selection.

[38] In NR, the possible periods (up to 16) in a resource pool are also configured in *ResourceReservePeriod* but the choice for these is largely extended and allow any integer value between 1ms to 99ms, with the multiples of 100ms up to 1000ms. Additionally, NR introduced several different mechanisms that need sidelink partial sensing. In NR, resource allocation for retransmissions is fully flexible in frequency and time, making it possible to reserve (one or two) retransmissions up to 32 logical time slots ahead. Reusing the prior art LTE partial sensing for NR, would require a very long bitstring indication to point to all possible instants in the 1100ms window.

[39] The apparatus, methods and systems described herein provide efficient signaling and configuration to enable the UE to perform partial sensing and still catch the possible reservations, both for retransmissions and for periodically reserved reservations, based on the periods defined in NR and retransmissions assignments.

[40] In a resource pool, a partial sensing UE can be configured or pre-configured to perform sensing of the slots that indicate retransmissions resources that may collide with a potential resource selected by the partial sensing UE for its own use.

[41] In NR, an SCI can reserve retransmissions up to 32 logical slots in advance (in LTE, up to 16). To make sure that there is no ongoing reservation of retransmissions over the resource selected for evaluation, partial sensing UEs perform sensing on all logical slots before the selected slot that is in the range of the retransmission time resource indication.

[42] Listening to these 16 or 32 slots can prevent listening to the full sensing window of 100ms (for aperiodic resource pool; 1100ms for a resource pool with periodic reservation allowed) and thus reduce power consumption.

[43] To limit the cost of sensing 16 or 32 slots prior to the selecting the required resources, the partial sensing UE may be configured to sense only part of available slots, following a (pre)configured pattern. The possible patterns can be preset and signaled by (pre)configuration with an index, or alternatively use a bitmap that indicates which logical slots to sense.

[44] Figure 4 shows the slots that need to be sensed in order to determine if the desired Slot A is free. In this example, the partial sensing UE only senses 4 out of 8 (logical) slots prior to its selected resource to search for reservations of retransmissions.

[45] Figure 5 shows a missed retransmission reservation (SCI), leading to a collision in the desired Slot A. Limiting the sensing will save battery life but collisions with reservations of retransmissions may occur if it was reserved in a slot not sensed. This is a compromise that the configuration will set according to its traffic and the capability configured for each resource pool.

[46] Resource selection for retransmissions in a resource pool where partial sensing UEs are configured can be set so that retransmissions resources match the limited sensing time pattern. This limits the flexibility of resource allocation but allows partial sensing users to listen to all possible conflicting retransmission resource that could affect their resource selection.

[47] To do so, if the resource selection of a transmission and its retransmission are done at once in the Step 2 of NR Sidelink resource allocation Mode 2, to check that the chosen candidate is suitable for the time pattern configured. The time pattern must be reversed, as, for example, sensing 5 slots prior to an evaluated resource by a limited sensing user means a resource 5 slots ahead in time is reserving retransmissions. If the resources are independently selected for transmissions and retransmissions, then the apparatus, systems and methods described herein

may remove from the candidate set of resources in Step 1 any resources in the slots non-listened by the partial sensing users.

[48] The limited sensing can all be enabled/disabled using flags configured in the resource pool. This functionality can impact on resource selection flexibility and device power consumption, so it may be enabled when limited sensing UEs are present or expected in the resource pool.

[49] This method may be suitable for a resource pool with blind retransmissions that always use the retransmission resources reserved. HARQ feedback-based retransmission resource pools may also benefit from this approach.

[50] Partial sensing UEs may exchange capabilities between UEs and/or with network, and the partial sensing UE capability can define which sensing method and/or how much sensing, e.g. per evaluated resource or per time unit, the partial sensing UEs can perform. When this information is exchanged, the resource pool can be configured appropriately for example by determining which set of resource to listen to and whether to manage the capabilities and expectations of various partial sensing UEs.

[51] The methods presented herein function without distinguishing whether the resource pool is configured for aperiodic resource only or periodic reservations and are therefore capable of catching the reserved retransmissions of both kinds.

[52] These limited sensing methods are applied by partial sensing UEs with limited sensing capabilities and not necessarily by all users of the pool, even if the resource pool is configured with these methods as enabled. The configuration can affect the other partial sensing UEs that are not configured by systems and methods described herein, by limiting their resource selection, for instance.

[53] Partial sensing UEs can be configured to perform sensing of a limited set of slots in a resource pool, including all the slots that coincide with the configured possible periods of reservation that will collide with the evaluated resource. Thus, the partial sensing monitors the slots that correspond to times $t_{y-j \cdot P_i}$ for all the period values P_i configured in *ResourceReservePeriodList*, for all j such that $P_i \cdot j \leq \text{SensingWindow}$.

[54] Partial sensing UEs can be configured to perform sensing of a limited set of slots in a resource pool, including the N last slots that coincide with the configured possible periods of reservation that will collide with the evaluated resource. N can be (pre)configured, possibly for each period configured. Figure 6 shows an example where periods, selected for illustration, of 20ms and 50ms are configured in the resource pool. The partial sensing UE evaluates potential access in a slot marked Evaluated Resource A by sensing the Listened to slots every 20ms and every 50ms before Evaluated Resource A. Other slots are not required to be sensed or listened to. More particularly, sensing is performed on the exact slot that is at the time of possible periodic conflict, with the exact listening duration being limited to listening to the PSCCH to decode first stage of the SCI and possibly listening to the PSSCH for the second stage of the SCI of these specific slots to determine if it is an intended receiver of data.

[55] Thus, this proposed partial sensing requires the partial sensing UE to monitor the slots that correspond to times $t_{y-j \cdot P_i}$ for all the period values P_i configured in *ResourceReservePeriodList*, for all j such that $j \leq N$.

[56] In order to reduce sensing time and so power consumption, $N=1$ is used, and only the slots that correspond to the last occasion of a time difference equal to the configured possible periods are sensed. In Figure 7, only one slot per configured period is sensed; that is the slot 50 ms before Evaluated Resource A and the slot 20 ms before Evaluated Resource A. If the slot corresponding to the time instant of a potential periodic reservation collision is not a SL slot, then

the partial sensing UE may sense the instant that is the last SL slot occasion corresponding to such periodicity.

[57] When anypartial sensing UE that performs a periodic reservation does not have a data to transmit, it simply does not transmit on the reserved resources. Thus, a partial sensing UE sensing only the last occasion ($N=1$) is not guaranteed to know for sure whether a resource was periodically reserved at that time. Thus, to improve reliability, it is possible to set $N>1$.

[58] To reduce the sensing time, it is further possible to configure limited sensing UEs to only sense the slots corresponding to a subset of the possible periods. This may generate collisions for the benefit of power saving. The period to sense, for example *ReducedSensingPeriodList*, can be configured and signalled with a bitmap of the same length as the possible period list.

[59] Alternatively, the apparatus, methods and systems may set a minimum and/or maximum period value for the periods to be sensed. These limited sensing periods can be configured to match the partial sensing UE capabilities that are signalled over the resource pool. Thus, this partial sensing monitors the slots that correspond to times $t_{y-j \cdot P_i}$ for the period values P_i in the configured subset *ReducedSensingPeriodList*, for all j such that $P_i * j \leq \text{SensingWindow}$ (or $\leq N$).

[60] Partial sensing UEs can be configured to perform the partial sensing methods described herein over a limited sensing window.

[61] In NR, the window for periodic enabled resource pool is 1100ms, which is long relative to the many occasions of small period reservations. Thus, the reservation pool allows limited sensing users to reduce their sensing windows to a minimum size, for example 100ms. The exact value of window sensing can be left for implementation but may be constrained to that configured minimum. UEs with limited sensing features can share their user limited sensing capability including the maximum sensing window size possible.

[62] The apparatus, methods and systems described herein can be configured or preconfigured and activated/deactivated with a dedicated flag in the configuration, or simply by the presence or absence of the required configuration parameters. Such change in configuration can be triggered by the presence of limited sensing UEs and their capability.

[63] Typically, the sidelink resource pools will allow both aperiodic transmissions with multiple repetitions reserved in a single SCI, transmissions with periodic reservation of resources, and periodic reservations may also have retransmissions. In addition, the periodic transmissions may need to resort to one shot transmissions, for example in case HARQ NACK is received and re-transmissions can be performed within the packet delay budget. The UEs with constrained power need to apply a combination of the strategies described herein to minimize their sensing requirements.

[64] Thus, the partial sensing UEs will listen to a group of resources just prior to their selection window (the Evaluated Resource A) to detect any retransmission reservations potentially colliding with the candidate resource, and then beyond that will sense over the slots which correspond to the periodic instances for the periods configures as part of the resource pool configuration.

[65] Resource pool configuration can indicate with suitable fields the bounds on the two intervals of partial sensing. The partial sensing bounds may be linked to the priority of the transmissions. As a simple example, the resource pool configuration can define a priority threshold and if the power constrained UEs are transmitting a packet which has priority higher than the configured threshold, they can perform sensing with one indicated bound, for example both periodic and aperiodic partial sensing limited to a duration of 100ms. If the priority of the packet is equal or lower than the configured threshold, these UEs will perform partial sensing over

longer durations, either spanning the full sensing window or indicated by configuring an explicit duration as part of resource pool configuration.

[66] In the partial sensing methods described herein and to further reduce the power consumption due to monitoring radio resource, UEs with limited sensing capabilities can be configured to stop or pause their monitoring for the set of slots/sub-channels that correspond to potential reservation announcement of an already reserved resource.

[67] For example, in Figure 8 an SCI is monitored in one of the possible conflicting reservation slots sensed by the partial sensing UE. The SCI reserves resource overlapping with the Evaluated Resource A for another UE. The sensing for future conflicting reservations is stopped and set as non-available, with a new Evaluated Resource selected from one of the other resources in the Y list.

[68] Optionally, the partial sensing UE may sense the last occasion of the reservation conflict occasions to verify if the periodic resource is still using the periodic resource. Note that if the limited sensing UE is considering several frequency-divided resources (different sub-channels) in a same slot, and if only part of that slot is already reserved, the limited sensing UE can still monitor the remaining slots to check for further conflicts with the non-conflicted resources. This will still require partial sensing UE to have its radio reception active, but it can reduce the decoding and processing to the PSCCH areas that may still lead to further conflicts.

[69] This interrupted sensing can apply both to periodic reservation partial sensing and retransmission partial sensing. In the case of periodic reservation partial sensing, the potential conflicting occasions are using the same sub-channel as the selected resource and these can be easily identified and removed from sensing. In the case of retransmission partial sensing, retransmission resources have full flexibility in time and frequency domains, thus to interrupt sensing over slot occasions that has potential conflicts, all the candidate resources of a selected slot must be already be reserved to cancel the monitoring of the corresponding slots.

[70] Set out below are various techniques related to power consumption for sidelink communications, in particular to reduce power consumption during sensing and transmission operations by coordination of resources. As set out below Power Saving UEs (PSUEs – defined as UEs utilising power-saving techniques such as a partial sensing) share information on monitored and transmission slots to assist other UEs in coordinating their transmissions. The other UEs may use the slots indicated as being monitored to transmit data or configuration/RRC information to the PSUE, reservation information relevant to the PSUE (the PSUE may not be the destination of the reservation, but the reservation may affect which resources the UE will select for its transmission), or coordination information that the UE needs to be aware of. Similarly, other UEs may use non-monitored slots for transmissions that are not relevant to the PSUE as a priority over slots that are monitored.

[71] As discussed above a PSUE may be configured in a partial sensing mode such that it only monitors a subset of transmission slots/resources prior to selecting transmission resources. It is assumed that the monitored resources are related to the resources which may be used for transmission, such that in relation to a slot containing potential transmission resource the PSUE monitors a (pre)defined set of previous slots. The slots are monitored to detect periodic reservations or retransmission reservations. When monitoring a PSUE has to listen to whole slots for potential reservations, and has to try and decode SCIs in all possible PSCCH of each monitored slot. It is then already in a listening mode with radio receive hardware and decoding capabilities on for the whole slot. The PSUE can be configured to be able to receive data in the monitored slots, it shall also decode the 2nd stage SCI in the corresponding PSSCH, to check if it is the destination. If it is then it can further decode a PSSCH payload transmitted in the same slot,

meaning data can be received in a single “on” period for the receiver, rather than turning on only to receive scheduling information. In NR, the reservation mechanism for retransmission allows to reserve any time-frequency resource in a given future window (32 slots). Since the frequency of that resource can be changed (and indicated in the SCI of reservation), when a UE wants to monitor for potential reservations conflicting a candidate resource, it will have to decode all possible frequency position of the SCIs in the monitored slots. For periodic reservations and monitoring, a periodic reservation automatically reserves the same frequency resource in the future as the one being sent. However, since the size of the resource can vary, a PSUE still shall monitor most of the possible PSSCH position for potential conflicts.

[72] In an example, a PSUE may be (pre-)configured to be a sidelink receiver and applies partial monitoring of slots based on a configuration. The PSUE may select slots to be monitored based either on a configuration defined for the UE or based on the configured candidate transmission slots and sensing patterns. The PSUE communicates information regarding the monitored slots to other UEs, either explicitly or implicitly. UEs transmitting to the PSUE utilise the shared information as an input to slot selection for transmissions.

[73] The slots to be monitored by a PSUE are defined in a deterministic manner. For example, the slots may be (pre)defined for the PSUE and shared between relevant devices, alternatively the PSUE’s transmission slots may be (pre)defined and shared such that the monitored slots can be derived from their relationship to the transmission slots.

[74] In a first approach the PSUE defines a set of monitored slots and transmits information regarding those slots to other UEs. The monitored slots may be selected from the receive resource pool configured for the PSUE. Information on the set can be shared with other UEs using an appropriate format, for example a bitstring or equivalent pattern. The PSUE may use the PSSCH “MAC level” information coordination. The PSSCH data can be transmitted as a unicast or groupcast transmission to relevant UEs, or as a broadcast transmission to all UEs with reception range. The monitoring sequence length and periodicity can be (pre)configured for a PSUE or for the relevant resource pool. This approach is anticipated to be straightforward to implement but incurs overhead in the periodic transmission of information on the monitored slots.

[75] The set of monitored resources may be defined as a Power Saving Resource Pool (PSRP) for PSUE(s). In an example it is a (sparse) receive resource pool. Such resource pools may be defined with parameters intended to enable power saving behaviour by PSUE(s). PSUE(s) may be configured to monitor all slots in the PSRP, as a normal UE would do in its assigned resource pool. The slot structure of the PSRP defines the extent of monitoring by the PSUE. A PSRP can be configured to be relatively sparse in the time slot allocation to avoid PSUEs being active over too many slots which would increase power consumption. A dedicated slot selection format or predefined sequence(s) can be defined to provide a sparse slot structure for the PSRP.

[76] When the PSRP is configured, other UEs transmitting to a PSUE configured with the PSRP utilise the PSRP resources to transmit to the PSUE.

[77] To avoid limiting the access of UEs without power saving requirements to transmission resources, other UEs may be configured with a resource pool with which the PSRP overlaps. This resource pool and the PSRP should have similar PHY structure and configurations (e.g. sub-channel size, SCI format, PSFCH design...).

[78] UEs may be configured with several resource pools, with one resource pool being active at any time. Some of the resource pools configured for a UE may be PSRPs, which may be indicated implicitly by their characteristics (e.g. sensing patterns), or explicitly using an indicator such as a flag.

[79] As will be appreciated, to avoid misunderstanding in timings and reservations, UEs will need to convert the logical slots used with regular resource pools and PSRPs to know when reservations and transmissions actually happen. This can be done if UEs are aware of the different resource pools which are active at each time.

[80] In a particular example, the PSRP may be defined as a subset of a resource pool. The PSRP may be defined as a sub resource pool within a resource pool, with the sub resource pool only be used by PSUE receivers. The subset of slots is sent by (pre)configuration and can be based on a sequence of binary logical slots selecting which slots of the resource are included in the PSRP. The configuration of the PSRP is similar to the main resource pool it is associated with, but with only a subset of the slots. This avoids configuration compatibility issues and saves configuration overheads or logical time issues. UEs communicating with a PSUE should use the PSRP subset to perform their transmissions. UEs communicating with non-PSUEs should prioritize the use of resources that are not in the PSRP subset to perform their communications, keeping the PSRP resources free.

[81] The PSRP (pre)configuration information is shared with other UEs to inform them of which slots the PSUE is monitoring. The (pre)configuration information may be shared as RRC parameters or preconfigured to the UEs. Each UE is thus made aware of other UE's reception capabilities during connection configuration providing a stable, non-dynamic, modification which is preferable as the monitoring periods can be long and so a stable configuration is preferable.

[82] As noted above, monitored slots may also be defined based on a deterministic definition of transmission slots. A PSUE's transmission slots may be defined (either selected by the PSUE, or by configuration) sufficiently early that the corresponding monitoring slots are known and can be shared with other UEs to utilise.

[83] The transmission slots can be defined as:

- A dedicated transmission resource pool. The transmission pool for a PSUE can be set to be sparse enough (to ensure limited sensing and processing) and accommodate the good behaviour of the monitoring pattern (e.g. by using slots whose monitoring pattern will coincide with each other).
- A subset of a regular transmission pool. A binary set of slots matching a configured transmission pool can be applied to down-select the slots of the transmission pool which will be possible transmission slots for the PSUE.
- Within a regular transmission resource pool, where the PSUE additionally uses transmit opportunities defined dynamically by the PSUE.

[84] The partial sensing performed by a PSUE corresponds to (pre)defined patterns that the PSUE monitored in the past to check for reservations that would coincide with the transmission resource it expects to use. The patterns can be made to check for retransmission reservations (using logical slots) and/or periodic reservations (absolute time). The patterns to be used may be predefined, reused from other systems (for example LTE), or configured specifically for NR sidelink communications. Using the patterns, and the (pre)defined transmission slots, the PSUE can derive the slots to be monitored prior to those transmission slots.

[85] A PSUE may be configured to transmit its transmission slots to other UEs. The other UEs can combine this information with the (pre)configured partial sensing patterns to derive which slots the PSUE will be monitoring. If the transmission slots are defined as dedicated resource pools or sub-resource pools, the configuration of these pools can be shared (as RRC messages) between UEs. If several transmission resource pools are configured, the PSUE can exchange the reference (e.g. index) of the active transmission resource pool used with the other UEs.

[86] If the transmission slots are directly defined by the PSUE, it must transmit its expected transmission slots to other UEs in advance. This can be done dynamically, using PSSCH to carry the information. The transmission can be made regularly (e.g. using a periodic transmission) to update other UEs, or on-demand, to update other UEs whenever a configuration update or new setting is available. This transmission can be a unicast/groupcast (targeting individual users/groups connected to the PSUE), or broadcast (to inform to all UEs within reception range).

[87] UE's receiving PSUE reservations in the future assume the corresponding slots are the PSUE's transmission opportunities. When a PSUE sends a reservation of resource in the future, it means that the PSUE will transmit in that slot. This can be for retransmission or periodic reservation. When UEs monitor and receive such reservations by a PSUE, they can assume the reserved slots are in the PSUE's transmission slots and therefore derive the expected monitored slots based on these reservations and the partial sensing patterns. UEs can also use a PSUE's reservation history and statistics compiled locally to deduce the PSUE's usual transmit slots and assume they are the PSUE's future transmit slots as well.

[88] A PSUE can determine the position and frequency (or density) of transmission opportunities based on its traffic, traffic history, traffic type or QoS. If based on TX resource pools, a PSUE can adapt the TX resource pool used based on its traffic needs. Based on its ongoing or expected traffic, a PSUE can determine its need for transmission slots or transmission slot opportunities. The transmission slot candidates should reflect that each potential transmission will consider a resource selection window that includes several resource candidates (at least Y in the LTE version). For instance, a traffic with deterministic time of arrival of packets can anticipate its transmission needs. A change in traffic requirements can trigger a change of transmission configuration (e.g. transmission pattern or transmission resource pool used) and this change shall be reported to the other UEs.

[89] Set out below are examples of communication processes for communicating with a PSUE which has applied the principles described above to define and share its monitoring and transmission slots.

[90] Conventional NR Mode 2 resource selection procedures use two principle steps. The first is identification of available/candidate resources and the second is selection of resources for transmission, which selection is made from the candidate resources.

[91] In a first example of using shared information, when selecting resources a UE may define candidate slots for transmission as the slots monitored by the PSUE. As a first step in the identification phase of resource selection, a transmit UE will check for all the candidate resources in a set of slots that may correspond to the transmit resource pool of the UE which fall into the resource selection window. In particular in the conventional procedure:-

Notation: $(t_{0SL}, t_{1SL}, t_{2SL}, \dots)$ denotes the set of slots which can belong to a sidelink resource pool and is defined in Clause 8.

1) A candidate single-slot resource for transmission $R_{x,y}$ is defined as a set of L_{subCH} contiguous sub-channels with sub-channel $x+j$ in slot $tySL$ where $j=0, \dots, L_{subCH}-1$. The UE shall assume that any set of L_{subCH} contiguous sub-channels included in the corresponding resource pool within the time interval $[n+T_1, n+T_2]$ correspond to one candidate single-slot resource, where

- selection of T_1 is up to UE implementation under $0 \leq T_1 \leq T_{proc,1SL}$, where $T_{proc,1SL}$ is defined in slots in Table 8.1.4-2 where μ_{SL} is the SCS configuration of the SL BWP;

- if T_{2min} is shorter than the remaining packet delay budget (in slots) then T_2 is up to UE implementation subject to $T_{2min} \leq T_2 \leq \text{remaining packet budget (in slots)}$; otherwise T_2 is set to the remaining packet delay budget (in slots).

The total number of candidate single-slot resources is denoted by M_{total} .

[92] The first part of this process is modified so that the output of the first step of the identification corresponds to the resources that fall both into the resource selection window, the set of slots of the transmit resource pool and the monitored slots of the PSUE.

[93] This can be done by either:

- MAC down-selecting the slots used as input of the process (i.e. the $(t_{0SL}, 1SL, t_{2SL}, \dots)$ slots); This means that the coordination between the PSUE monitored slots and UEs transmitting to it can be kept at the MAC level.
- or PHY doing the down-selection by keeping the original set of slots but down-selecting is performed in the step 1 by changing the included slots or i.e. a subset of $j=0 \dots L_{subCH}$ to be the slots monitored only. This requires that the information of the monitored slots by PSUE is exchanged from MAC to PHY layers (assuming that it is originally known by MAC).

[94] In this example, the total of candidate resource M_{total} only includes candidate transmission slots for both the UE transmitting and the PSUE receiving. This set is however still subject to further exclusions and down selection as per the usual process.

[95] In a second example, the exclusion step of the identification of candidate resources may be modified to remove resources in slots not monitored by the PSUE. In the conventional procedure for identification of resource, resources are excluded if they meet certain conditions:-

5) The UE shall exclude any candidate single-slot resource $R_{x,y}$ from the set S_A if it meets all the following conditions:

- the UE has not monitored slot t_{mSL} in Step 2.
- for any periodicity value allowed by the higher layer parameter $sl\text{-}Resource\text{ReservePeriodList}$ and a hypothetical SCI format 1-A received in slot t_{mSL} with "Resource reservation period" field set to that periodicity value and indicating all subchannels of the resource pool in this slot, condition c in step 6 would be met.

6) The UE shall exclude any candidate single-slot resource $R_{x,y}$ from the set S_A if it meets all the following conditions:

- a) the UE receives an SCI format 1-A in slot t_{mSL} , and "Resource reservation period" field, if present, and "Priority" field in the received SCI format 1-A indicate the values P_{rsvp_RX} and $priorX$, respectively according to Clause 16.4 in [6, TS 38.213];
- b) the RSRP measurement performed, according to clause 8.4.2.1 for the received SCI format 1-A, is higher than $Th(priorX)$;
- c) the SCI format received in slot t_{mSL} or the same SCI format which, if and only if the "Resource reservation period" field is present in the received SCI format 1-A, is assumed to be received in slot(s) $t_{m+q \times Prsvp_RX' SL}$ determines according to clause 8.1.5 the set of resource blocks and slots which overlaps with $R_{x,j \times Prsvp_TX'}$ for $q=1, 2, \dots, Q$ and $j=0, 1, \dots, C_{resel}-1$. Here, $Prsvp_RX'$ is $Prsvp_RX$ converted to units of logical slots according to clause 8.1.7, $Q = \lceil T_{scal} Prsvp_RX \rceil$ if $Prsvp_RX < T_{scal}$ and $n'-m \leq Prsvp_RX'$, where $t_{n'SL} = n$ if slot n belongs to the set $(t_{0SL}, 1SL, \dots, t_{TmaxSL})$, otherwise slot $t_{n'SL}$ is the first slot after slot n belonging to the set $(t_{0SL}, 1SL, \dots, t_{TmaxSL})$; otherwise $Q=1$. T_{scal} is set to selection window size T_2 converted to units of ms.

[96] In this example, the exclusion steps are modified to add the exclusions of resources that are not monitored by the PSUE. In this example, MAC shall inform PHY of which slots are monitored by the targeted PSUE (assuming MAC originally detains the information). M_{total} includes all the resources which are initially candidates from the transmitter point of view, while the number of candidate resources available after exclusion considers both transmitter, sensing and PSUE constraints.

[97] When step 7 above (3GPP TS 38.214 Section 8.1.4: checking that the output contains at least X. M_{total} number of resources) is performed, the first alternative is more likely to satisfy the X requirement, since M_{total} only includes the resources that are monitored by PSUE and hence it is less likely to increase the RSRP power threshold to include more resources, giving some more

interfered resources for the MAC layer. However, the number of resource given by the first alternative is smaller than the second alternative, giving fewer choices for the MAC layer to select.

[98] In a third example the resource selection may be modified so that candidate resources belonging to non-monitored slots are removed. Instead of excluding resources not monitored by the PSUE in the PHY layer, it can be done at the MAC layer after the resource identification is completed. The conventional resource identification process is utilised but after reporting the set of available resources, the MAC layer excludes the non-monitored resources before selecting the actual transmission resource.

[99] Note that since the PHY layer doesn't remove the non-monitored slots, it may be possible that few or none of the given resources are actually suitable. In that case, the MAC layer can either drop the transmission or perform a reselection, given a more suitable set of slots to select from (i.e. similar to the first alternative).

[100] When a UE is preparing resources to be transmitted toward a PSUE, the parameters X and RSRP thresholds can be configured separately from the ones towards regular users. This leads to an extra RRC configuration for the receiving RP of PSUEs. For instance, X can be set to higher values to ensure a larger number of candidates that may further be down-selected (especially in the case where M_{total} includes potentially non-monitored resources by the PSUE).

[101] In current LTE, power limited users "Pedestrian UE" can be configured to perform only transmissions, in particular for the case of period transmission of the user position/id. In this case, the UE is not required to perform any sensing prior to the transmission, which can lead to collisions. Power limited users can also be configured to perform partial sensing to be able to receive some data or to perform more reliable resource selection (avoiding collision).

[102] Herein it is disclosed that PSUEs are (pre-)configured to enable or disable the reception of sidelink transmissions. This (pre-)configuration follows the UE capability that specifies that this PSUE is capable of power limited reception of sidelink data. Since destination ID of a sidelink message is specified in the second stage SCI, and the reservation patterns/periodicity are in the first stage SCI, the following is observed:

- When not configured as "receiving capable", PSUEs performing some sensing (e.g. partial or full sensing), are only expected to decode the 1st stage SCI, i.e. the PSCCH, to get the information of resource reservations.
- When configured as "receiving capable", PSUEs are expected to sense and decode both 1st stage and 2nd stage SCIs, and possibly the data payload when the PSUE is the destination of the transmission.
- For PSUEs with receive capabilities, it can be configured that they are required to listen to 1st and 2nd stage SCIs only in the slots they are configured to monitor; while possibly listening to only 1st stage SCIs or nothing in other slots (slots split can be based on the configured RP and PSRP for example).

[103] When a PSUE is configured as a 'receiver', and when the monitoring is based on the TX selected slots, as long as the PSUE has data to transmit, it will sense regularly. If the PSUE doesn't have data to transmit, it shall still monitor a pattern known to other UEs to accept some RX. The PSUE can be configured (temporarily) as a limited receiver/ can use specifically defined patterns/ sub-pattern of regular partial sensing.

[104] When a PSUE is receiving a data on a sparse monitoring pattern, it can trigger a change into a more frequent monitoring pattern if the received data and connection requires a QoS not compatible with the sparse monitoring.

[105] In summary, there are provide various methods of sidelink communications between UEs. A UE may be configured to only monitor a subset of slots and may communicate information on

those slots to other UEs either explicitly or implicitly. The UE may communicate transmission slots from which monitored slots can be identified. UEs communicating with a UE which has specified its monitoring slots should only transmit to that UE in those monitored slots. When selecting sidelink transmission resources, particularly in Mode 2, UEs should base the selection, at least in part, on the indication of monitored slots.

[106] 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.

[107] 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.

[108] 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.

[109] 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.

[110] 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.

[111] 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.

[112] 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.

[113] 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.

[114] 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.

[115] 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.

[116] 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.

[117] 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.

[118] 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.

[119] 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.

[120] 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 sidelink communication between at least two UEs in a cellular communications network, the method comprising
defining a power saving resource pool for use by power saving UEs;
transmitting an indication of the transmission resources in the power saving resource pool from a base station to at least the at least two UEs; and
when communicating to, or transmitting from, a power saving UE utilising only transmission resources of the power saving resource pool.
2. The method of claim 1, wherein the power saving resource pool is defined as a subset of a resource pool defined for use by the at least two UEs.
3. The method of claim 2, wherein the power saving resource pool is defined as a sub set of slots within the resource pool.
4. The method of any preceding claim, wherein the indication of the transmission resources in the power saving resource pool is sent utilising RRC signalling.
5. The method of any preceding claim, wherein prior to transmission a power saving UE monitors only slots in the power saving resource pool.
6. The method of any preceding claim, wherein a UE utilising the power saving resource pool transmits an indication to other UEs of resources in the power saving resource pool.
7. The method of any preceding claim, wherein the power saving resource pool is defined by a UE utilising that resource pool.
8. The method of any preceding claim, wherein the power saving resource pool is defined by a base station.

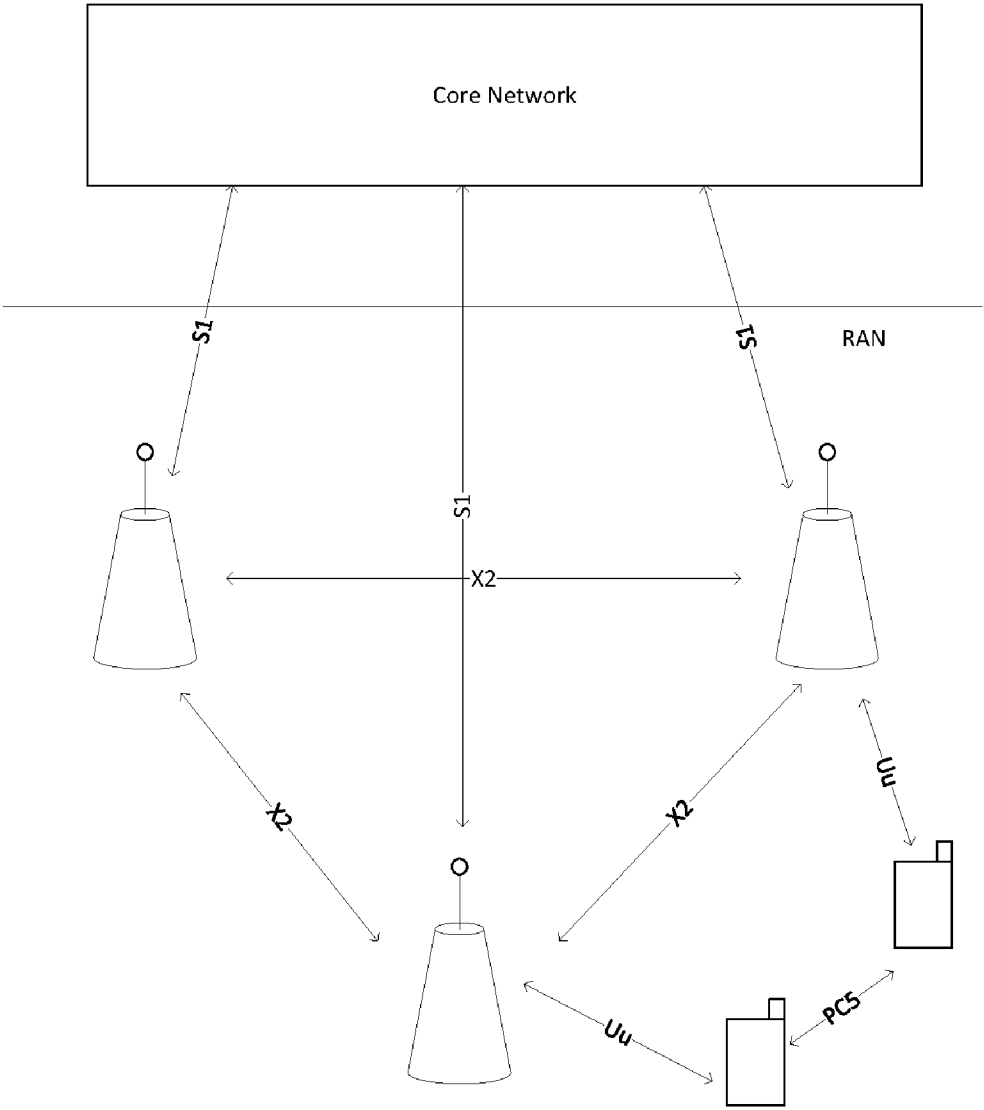


Figure 1

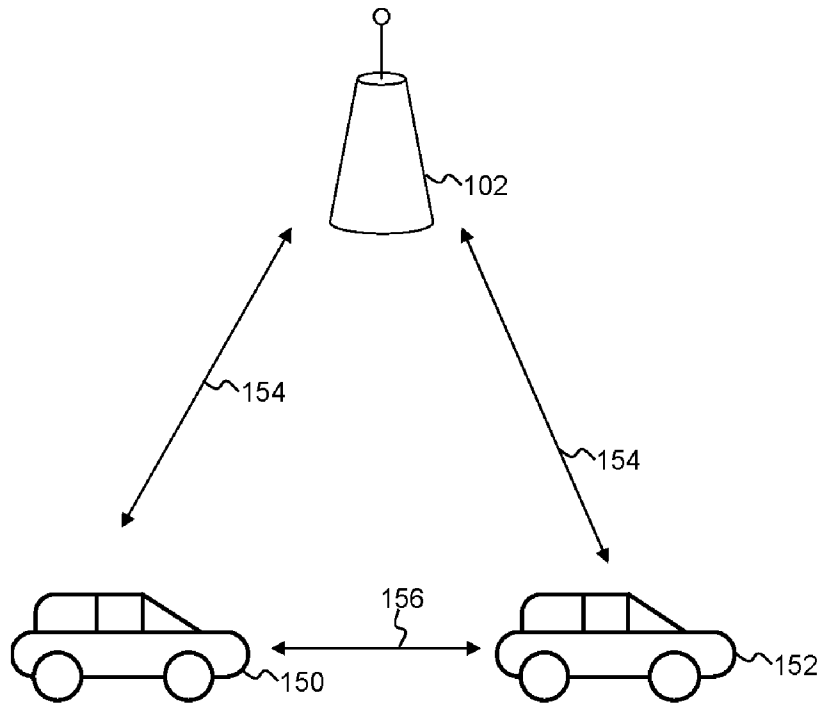


Figure 2

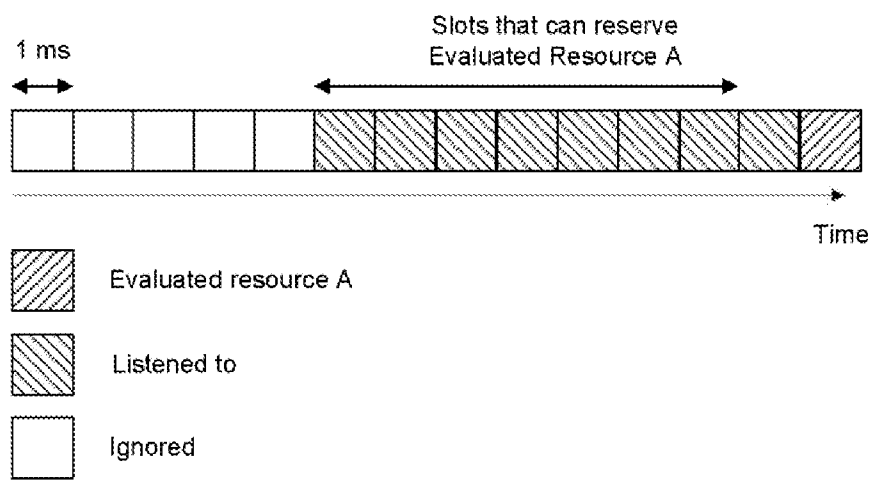


Figure 3

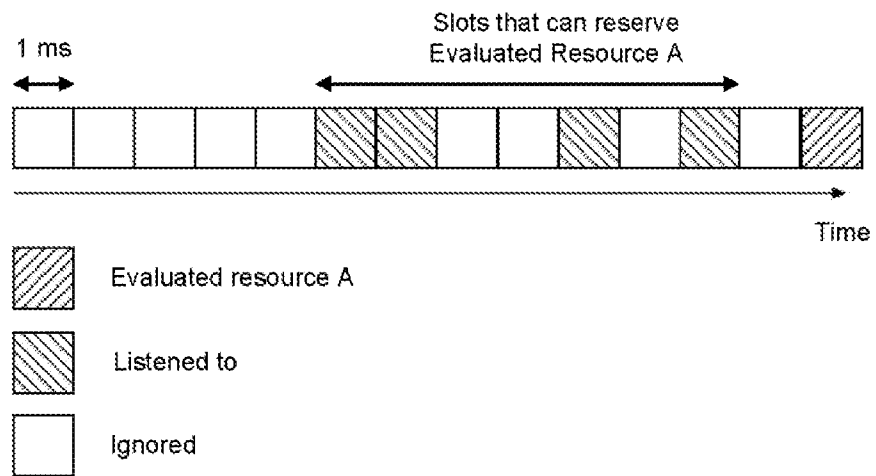


Figure 4

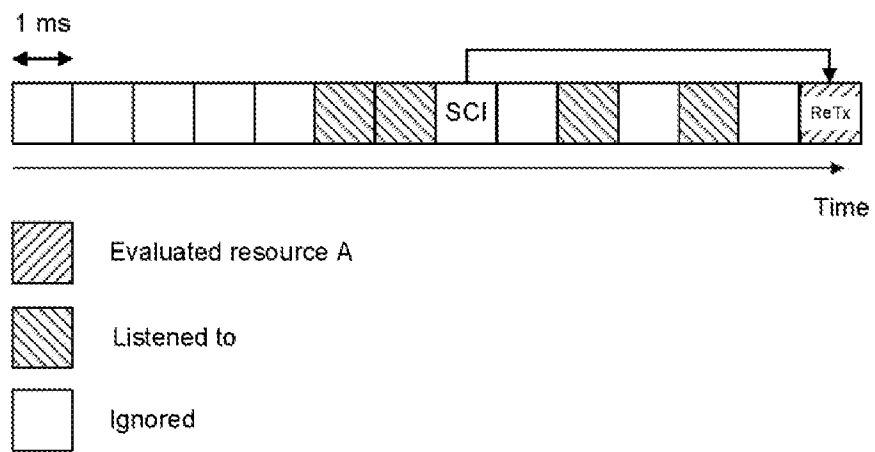


Figure 5

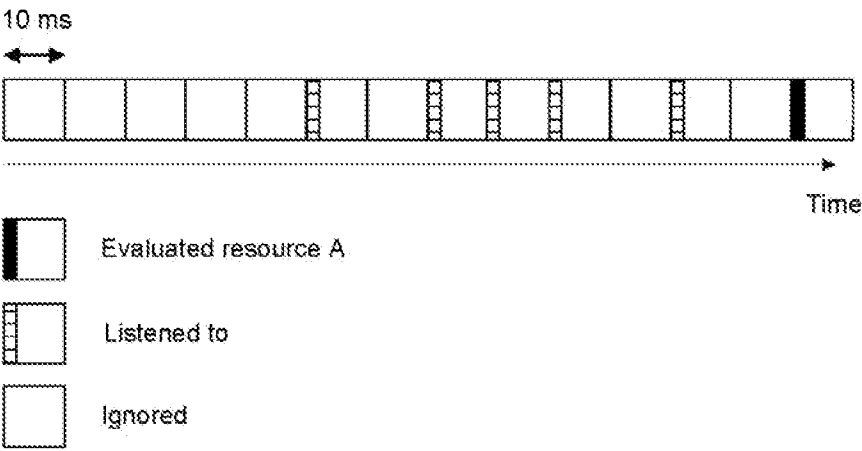


Figure 6

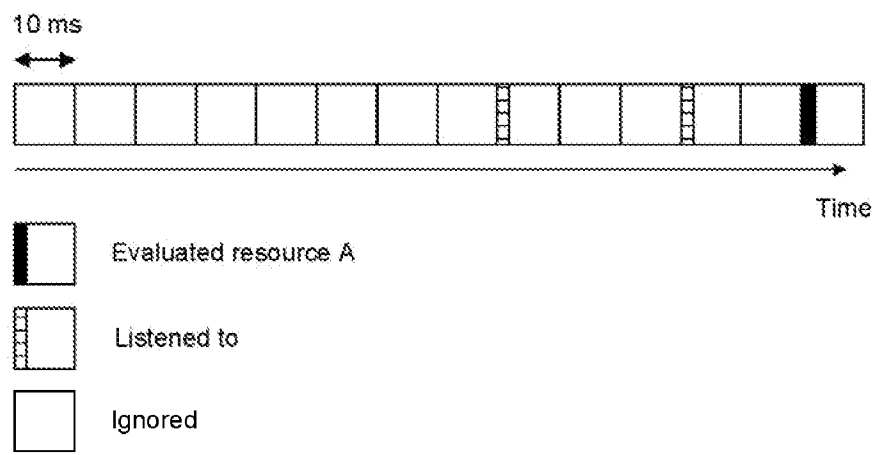


Figure 7

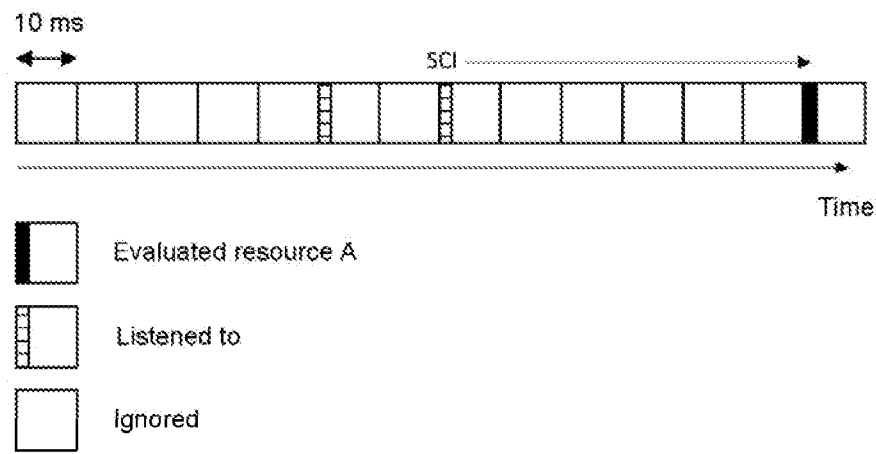


Figure 8

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2021/121851

A. CLASSIFICATION OF SUBJECT MATTER

H04W 72/04(2009.01)i; H04W 76/14(2018.01)n

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)

CNPAT, WPI, EPODOC, 3GPP: sidelink, PC5, V2X, V2V, D2D, direct, power saving, reducing, consumption, UE, PSUE, partial sensing, P-UE, resource pool, PSRP, RP, sparse, monitor, slot, RRC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	TCL COMMUNICATION. "Resource allocation for power saving" <i>R1-2007892</i> , 3GPP TSG RAN WG1 #103-e, 01 November 2020 (2020-11-01), pages 4-6	1-8
X	COOLPAD. "Discussion on power saving for P-UE" <i>R2-166594</i> , 3GPP TSG-RAN WG2 Meeting #95bis, 14 October 2016 (2016-10-14), pages 1-2	1-8
X	NTT DOCOMO, INC. "Discussion on sidelink resource allocation for power saving" <i>R1-2006747</i> , 3GPP TSG RAN WG1 #102, 28 August 2020 (2020-08-28), pages 1-3	1-8
A	US 2019373647 A1 (TELEFONAKTIEBOLAGET LM ERICSSONPUBL) 05 December 2019 (2019-12-05) the whole document	1-8
A	CN 106686736 A (YULONG COMPUTER TELECOMMUNICATION SCIENTIFIC SHENZHEN CO., LTD.) 17 May 2017 (2017-05-17) the whole document	1-8



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

16 December 2021

Date of mailing of the international search report

30 December 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

LUO, Xiao

Telephone No. 86-(10)-53961774

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2021/121851

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 108024283 A (CHINA ACADEMY OF TELECOMMUNICATIONS TECHNOLOGY) 11 May 2018 (2018-05-11) the whole document	1-8

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2021/121851

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
US	2019373647	A1	05 December 2019	EP	3536083	A1	11 September 2019
				WO	2018084796	A1	11 May 2018
CN	106686736	A	17 May 2017	WO	2018121148	A1	05 July 2018
CN	108024283	A	11 May 2018	None			