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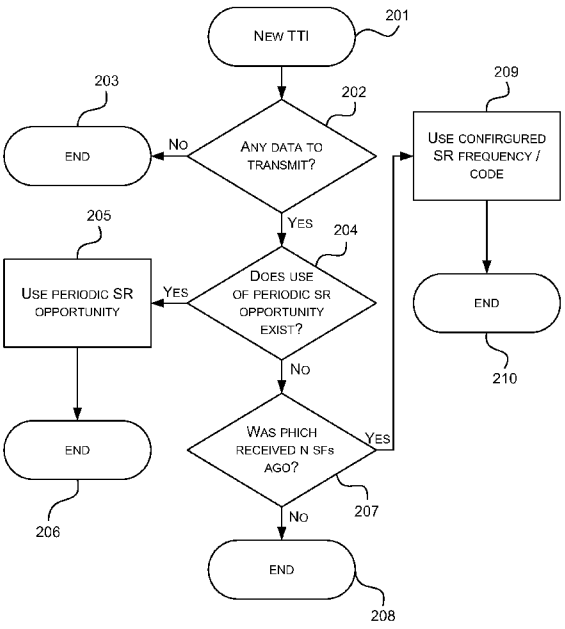


FIG. 2

(57) Abstract: A method and apparatus suitable for Long Term Evolution cellular communication systems (100) is provided which identifies spare, unused PUCCH (Physical Uplink Control Channel) resources which can be used by User Equipments (103a, 103b, 103c) for Scheduling Requests for data transmission. An evolved NodeB (101) can signal the availability of such resources to a UE using a PHICH (Physical Hybrid Activation Repeat Request Channel) or with Downlink Control Information (DCI).

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Cellular Communication System Devices

Technical Field

Embodiments of the present invention generally relate to cellular communications systems and in particular to devices and methods for determining a Scheduling Request opportunity configuration.

Background

Cellular 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. The 3rd generation of wireless communications has generally been developed to support macro-cell mobile phone communications. Such macro cells utilise high power base stations (NodeBs) to communicate with wireless communication units within a relatively large geographical coverage area. Typically, wireless communication units, or User Equipment (UEs) as they are often referred to, communicate with a Core Network (CN) of the 3G wireless communication system via a Radio Network Subsystem (RNS). A wireless communication system typically comprises a plurality of radio network subsystems, each radio network subsystem comprising one or more cells to which UEs may attach, and thereby connect to the network. Each macro-cellular RNS further comprises a controller, in a form of a Radio Network Controller (RNC), operably coupled to the one or more Node Bs. Communications systems and networks have developed towards a broadband and mobile system. The 3rd Generation Partnership Project has developed a Long Term Evolution (LTE) solution, namely, an Evolved Universal Mobile Telecommunication System Territorial Radio Access Network, (E-UTRAN), for a mobile access network, and a System Architecture Evolution (SAE) solution, namely, an Evolved Packet Core (EPC), for a mobile core network. A macrocell in an LTE system is supported by a base station known as an eNodeB or eNB (evolved Node B).

Before a UE can transmit data to an eNB it must receive a Scheduling Grant message from the eNB. In LTE systems, the so-called Scheduling Request (SR) is used by a User Equipment for requesting uplink resources for sending a new transmission of data. Typically, an eNB configures a UE with an SR configuration index via Radio Resource Connection (RRC) signalling in order for the UE to transmit a Scheduling Request on the PUCCH (Physical Uplink Control Channel). A particular SR configuration index has an assigned periodicity and subframe offset value. The SR index is used by the UE to determine the subframe where the scheduling request should be transmitted and thereby determine the next available opportunity for sending an SR. Scheduling Request periodicity is typically10ms so on average, a UE

will have 5 ms to wait for a PUCCH to become available. The time taken for the Scheduling Request sent on the PUCCH to reach the eNB is 1 ms. At the eNB, the Scheduling Request is decoded and the Scheduling Grant is generated. These decoding and generating steps can take of the order of 3 ms. Transmission of the Scheduling Grant from the eNB to the UE can take a further 1ms whereupon there is a further processing delay in the UE of typically 3 ms while the UE decodes the Scheduling Grant and encodes the uplink data. Transmission of the uplink data can take a further 1ms and decoding of the received data in the eNB can take a further 3 ms. Therefore, the total delay (or latency) associated with an uplink data transmission can total 17 ms.

It would be advantageous if this total delay could be reduced. A 1ms periodicity, if configured, could reduce the average waiting time for a PUCCH resource to 0.5ms for subframe alignment and thereby reduce the total average delay. However such configuration is regarded as inefficient from a resource utilisation point of view.

Summary

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.

According to a first aspect of the present invention, there is provided a method for determining a Scheduling Request configuration for a wireless communication device located within an area of coverage of a cellular communication system comprising one or more cells, the method including: monitoring an uplink scheduling load attributable to one or more wireless communication devices located within the cellular communication system, identifying spare resources on an uplink channel within the cellular communication system, allocating at least a portion of the identified spare resources for additional Scheduling Request opportunities for the wireless communication devices, and transmitting information relating to the identified spare resources to one or more wireless communication devices located within the cellular communication system.

According to a second aspect of the invention, there is provided a processing circuit for use in a network element which supports at least one cell in a cellular communication system, the processing circuit being adapted to monitor an uplink scheduling load attributable to one or more wireless communication devices located within an area of coverage of the cellular communication system; identify spare resources on an uplink channel within the cellular communication system; allocate at least a portion of the identified spare resources for additional Scheduling Request opportunities for the wireless communication devices; and determine a Scheduling Request configuration including information relating to the identified spare resources

for transmission to one or more wireless communication devices located within the cellular communication system.

According to a third aspect of the invention, there is provided a wireless communication device for use in a cellular communication system, wherein the wireless communication device is arranged to; establish a connection with a network element of the cellular communication system; receive an allocation of periodically-available resource for a Scheduling Request; receive an allocation of additional resources for a Scheduling Request opportunity; and if no periodically-available resource is currently available, transmit a Scheduling Request using an additional allocated resource.

In one embodiment the processing circuit is incorporated within a network element of the cellular communications system, such as an evolved Node B, for example. In other embodiments, the functionality of the processing circuit may be distributed between several network elements.

The cellular communication system may be an LTE system.

The wireless communication device may be a User Equipment or similar mobile communications device.

The processing circuit may be implemented in one or more integrated circuits.

The additional Scheduling Request opportunities may be signalled to a wireless communication device in a number of ways which will be described below.

According to a fourth aspect of the invention, there is provided a non-transitory computer readable medium having computer readable instructions stored thereon for execution by a processor to perform the method according to the first aspect.

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.

Embodiments of the invention introduce a physical layer enhancement in addition to accompanying L2/3 signalling to allow for a User Equipment, when in connected mode, to send a Scheduling Request to an eNB with less delay on average than is currently the case. In one embodiment, the eNB is provided with the ability to dynamically signal (to a UE) additional and more frequent Scheduling Request opportunities. In this way, the latency for transmission of a first uplink path packet from a UE to the eNB is reduced, on average.

The invention is particularly applicable to UEs which are operating in a connected mode and which are already semi-statically configured with periodic Scheduling Request opportunities.

In one embodiment, PUCCH resources are dynamically allocated for additional Scheduling Request opportunities to wireless communication devices.

The identified spare resources may be allocated to all wireless communication devices in a cell or to a subset of those wireless communication devices. Such a choice may be made based on a priority-based distribution of resources or on a fair and even distribution of resources, for example.

The invention advantageously reduces latency for a first uplink packet in a burst. Improving this parameter can have a significant effect on the TCP/IP (Transmission Control Protocol/Internet Protocol) slow start phase and therefore the overall throughput. Use of the invention can also induce a significant improvement for delay-sensitive applications. Furthermore, the invention can permit additional flexibility for a network scheduler. UEs may be configured with a lower SR opportunity periodicity but be allocated with more SR opportunities dynamically. This can result in a lower average latency while at the same time freeing up more resources while in high load situations. This benefit can be gained by dynamically scaling up or down the PUCCH/PUSCH (Physical Uplink Shared Channel) allocation. In contrast, when relying on only semi-statically controlling SR opportunity allocation, the network is forced to compromise either on latency or throughput. These advantages come with a very low penalty to uplink capacity. The network may decide according to the immediate load whether to allocate additional SR opportunities or not. The benefits are most noticeable in low and medium load situations and the network may scale down the number of additional SR opportunities in high load situations.

These and other aspects, features and advantages of the invention will be apparent from, and elucidated with reference to, the embodiments described hereinafter.

Brief description of the drawings

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.

FIG. 1 is a simplified block diagram of a part of a cellular communication system and operating in accordance with an example embodiment.

FIG. 2 is a simplified flowchart illustrating a first example of a method for determining and signalling a Scheduling Request configuration.

FIG. 3 is a simplified flowchart illustrating a second example of a method for determining and signalling a Scheduling Request configuration.

Detailed description of the preferred embodiments

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.

Referring now to FIG.1, an example of part of a wireless communication system operating in accordance with embodiments of the invention is illustrated and indicated generally at 100 and comprises an evolved Node B (eNB) 101 supporting an LTE cell 102. In other embodiments, the eNB 101 may support a multiplicity of cells. The evolved Node B 101 comprises a part of a radio access network which in this example is an E-UTRAN. User Equipments 103a, 103b, 103c are located within the area of coverage of the cell 102. Just three User Equipments are shown in FIG. 1 but more or fewer User Equipments may be located in the cell 102 and be in a connected mode at any given time. An evolved packet core (EPC) of the Wireless Communications System of FIG.1 includes a Packet Gateway P-GW 104 and a Serving GPRS (General Packet Radio System) Support Node (SGSN) 105. The P-GW 104 is responsible for interfacing the radio access network with a packet data network, eg. a Packet Switched Data Network (PSDN) (such as the Internet). The SSGN 105 performs a routing and tunnelling function for traffic to and from the cell 102, while the P-GW 104 links with external packet networks. The EPC also comprises a Mobility Management Entity 106. The eNB 101 is linked to the SSGN 105 through the Mobility Management Entity (MME) 106. The eNB 101 is also connected with the P-GW 104 through the MME 106 and a Service Gateway S-GW 107. The MME 106 handles signalling control and mobility while the S-GW 107 is a local anchor point for user data. The eNB 101 is provided with a processing circuit 108 whose function will be described below. The eNB also comprises a receiver (Rx) 109 and a transmitter (Tx) 110.

The processing circuit 108 monitors the uplink scheduling load within the cell 102 and identifies currently unused (and therefore spare) resources on the uplink channel. The processing circuit 108 then allocates at least a portion of the identified spare resources for additional Scheduling Request opportunities for one or more of the UEs 103a, 103b, and 103c which are currently in connected mode in the cell 102. The processing circuit 108 then determines a Scheduling Request configuration which includes information relating to the identified spare resources. The determined configuration is then transmitted by the transmitter 110 to one or more of the UEs 103a, 103b, 103c. The information contained in the Scheduling Request configuration tells a UE which PUCCH resources have been allocated for Scheduling Requests.

In a typical LTE system, the PUCCH is located at the extreme ends (or edges) of the system bandwidth in the frequency domain. In particular, in format 1 (including formats 1a and 1b), the PUCCH resource consists of one resource block at one edge of the system bandwidth which is followed by another resource block in the following slot (at the opposite edge of the channel spectrum). (A Resource Block is a unit of transmission resource consisting of 12 subcarriers in the frequency domain and one timeslot (0.5ms) in the time domain). In current LTE systems, PUCCH resources are allocated equally in both system bandwidth edges. In a first example of the invention, a sequential method of PUCCH resource allocation is performed which follows the same principle. The processing circuit 108 monitors the current uplink scheduling load and determines whether or not spare resources for scheduling requests are available. Additional PUCCH resources which have been identified by the processing circuit are allocated sequentially from both edges, inwards and towards the centre of the system bandwidth.

In a second example of the invention, an opportunistic method of PUCCH resource allocation is performed. This method of resource allocation is suitable for use with formats 1 (including 1a and 1b), 2 (including 2a and 2b) and 3. Conventionally, in formats 2 and 3, preconfigured resources for the PUCCH are allocated in a semi-static manner. However, not all of these resources are used (by a UE) in each and every subframe. This leads to fragmentation creating “holes” which can be used. Thus, by monitoring the current uplink load and identifying unused preconfigured resources, the processing circuit 108 can allocate these unused (additional) resources to one or more UEs 103a, 103b, 103c in the cell 102.

In both examples, the code, time and frequency of the additional resources are known to the relevant UEs by way of semi-static configuration or additional signalling.

The signalling of the additional PUCCH resource allocation (from the eNB 101 to a UE 103a, 103b, 103c) can be performed using one of several methods.

Conventionally, PUCCH resource is multiplexed with several SR transmissions from different UEs. The number of UEs multiplexed per PUCCH resource ‘n’ is semi-statically configured in the cell and broadcast as part of the SI (System Information). In one exemplary method of signalling according to the invention, the connected UEs are divided into groups of size equal to the multiplexing level ‘n’ (or a multiple of ‘n’) in the cell and signalled together for a dynamic additional SR opportunity. A semi static configuration is used consisting of association with a group and the PUCCH resource to be used within the group. For example a UE can be configured with a PUCCH resource index i. The group index would then be (floor of i/n) and the PUCCH resource within the group would be (i mod n).

In a first method, the PHICH (Physical Hybrid ARQ (Activation Repeat Request) Channel) is utilised by reusing and enhancing this channel. The processing circuit 108 in the eNB 102 semi-statically allocates additional PHICH REGs (Resource Element Groups). A PHICH orthogonal sequence index code may be associated, by means of dedicated semi-static signalling, with a group of n UEs (n being the PUCCH multiplexing level referred to above). The following table shows a possible PHICH REGs configuration. The number of REGs is determined by the system bandwidth and the so-called broadcast parameter 'Ng' which is signalled in the MIB (Master Information Block).

N_RB \ Ng	1/6	½	1	2
6 (1.4 Mhz)	1	1	1	2
15 (3 Mhz)	1	1	2	4
25 (5 Mhz)	1	2	4	7
50 (10 Mhz)	2	4	7	13
75 (15 Mhz)	2	5	10	19
100 (20 Mhz)	3	7	13	25

If, for example, a 10MHz system bandwidth cell may signal Ng=1 to indicate that 7 REGs are used (for the use of Ack/Nack signalling) then a value of Ng=2 could be signalled instead to indicate that 13 REGs are used and use the spare PHICH resources to signal the additional SR opportunities. When the processing circuit 108 in the eNB 102 allocates a PUCCH resource for a group of UEs for additional SR opportunity, the associated PHICH orthogonal sequence in the associated PHICH REG is transmitted.

In one example, a UE 103a, 103b, 103c is semi-statically configured with a frequency and/or code for SR transmission, that is; the UE is configured with the resource index i as described above.

Another option is to reuse the frequency/code configuration already provided by semi-static configuration for the periodic SR opportunity. A UE whose PUCCH group is signalled via PHICH for additional SR opportunities can transmit SR on the Nth subframe following the subframe in which the PHICH was received, (N being an integer known to all system elements in advance and which accounts for the time required by the UE for decoding and processing). N can be 1 or 2 or have a maximum value of 4, for example, while the frequency and code for SR transmission are determined as the same frequency and code which are configured for the periodic SR opportunity.

The flow chart of FIG. 2 illustrates an example of how a UE 102a handles the PHICH/PUCCH signalling method described above for a discrete transmission time interval (TTI). The process starts at 201 with the start of a new TTI. At 202, the UE

determines whether or not it has any data to transmit to the eNB (that is; if data is received, for transmission, from higher layers). If there is no data to transmit then the process ends at 203. If on the other hand, there is data to be transmitted, then the process proceeds to 204 where the UE determines whether it can use a (conventional) periodic Scheduling Request opportunity. If there is the possibility of using the periodic Scheduling Request opportunity then the process proceeds to 205 where the UE uses the periodic SR opportunity in the conventional manner with the process ending at 206. If no periodic SR opportunity is available, then at 207, if the UE did not receive information containing additional PUCCH resource on the PHICH 'N' subframes ago, (as mentioned above, in various embodiments N can be 1, 2 or a maximum of 4), then the process ends at 208. If however the relevant PHICH signal had been received N subframes ago, then the process can proceed to 209 where the UE extracts the SR frequency and code contained in the configuration of periodically-available resources and uses this information to access the spare, allocated PUCCH for a Scheduling Request. The process then terminates at 210.

Although the PHICH-based signalling method described above is very spectrally efficient, the required, additional PHICH resources need to be allocated semi-statically and signalled in MIB, which means that in times of heavy load, when it is not possible to allocate additional PUCCH resources, the additional PHICH resources would still have to be allocated. In a second alternative method, PUCCH resources are signalled with DCI (Downlink Control Information) instead. In this method, the UEs are divided into groups of size n*m (where n is the PUCCH multiplexing level as referred to above and m is an integer). Each group is associated with a unique Scheduling Request - Radio Network Temporary Identity (SR-RNTI) which is semi-statically configured for each UE along with a PUCCH index i relative to the group. A UE which needs to transmit a Scheduling Request decodes the DCI which is scrambled with its SR-RNTI and then calculates its SR resource according to the resource allocation in the DCI and the resource index it is configured with. The UE then maps the allocated Resource Blocks to a contiguous ordered list. The Resource Block which is allocated for the UE is the (floor (i/n) and the allocated code in this Resource Block is (i mod n). The resource allocation is signalled with DCI format 0 or alternatively with a new format including Carrier Indicator, Resource Block assignment, UL index, Resource allocation type. In one example, 'Resource allocation type' reuses the Rel-12 allocation types, that is; type 0 and type 2, in order to allow contiguous as well as non-contiguous resource allocation (for the case where m is greater than 1 and several PUCCH groups are allocated with a single DCI). The other field definitions in the alternative format comply with Rel-10 DCI format 0 fields. DCI received in subframe 'n' is normally pointing to subframe n+4 (in FDD-LTE (Frequency Division Duplex-LTE)), however this value can be considered as n+m where m is less than or equal to 4 (in FDD-LTE). In TD-LTE (Time Division-LTE), these values may be different.

The flow chart of FIG. 3 illustrates an example of how a UE 102a handles the DCI signalling method described above for a discrete transmission time interval (TTI). The process starts at 301 with the start of a new TTI. At 302, the UE determines whether or not it has any data to transmit (to the eNB). If there is no data to transmit then the process ends at 303. If on the other hand, there is data to be transmitted, then the process proceeds to 304 where the UE determines whether it can use a (conventional) periodic Scheduling Request opportunity. If there is the possibility of using the periodic Scheduling Request opportunity then the process proceeds to 305 where the UE uses the periodic SR opportunity in the conventional manner with the process ending at 306. If no periodic SR opportunity is available and at 307, no DCI scrambled with SR-RNTI was received and decoded m subframes ago (where m is less than or equal to 4 in the FDD-LTE case), then the process ends at 308. If however the relevant DCI was received and decoded m subframes ago, then the process can proceed to 309 where the UE calculates its dedicated SR resource (from the DCI) and at 310 uses the configured SR frequency and code to access the spare, allocated PUCCH for a Scheduling Request. The process then terminates at 311.

In another embodiment, a UE is configured with more than one resource index with the intention to allow the UE to belong to more than one PUCCH group for a more flexible allocation. For example, UEs designated as low priority could belong to a single group while high priority users or critical mission applications may belong to several groups.

In a further embodiment, a UE is configured with more than one resource index with the intention to allow the UE to signal SR on different resources in the same subframe or in another subframe. The particular resource that the UE selects to use may serve as an' indication' for the eNB. In particular, it may serve as an indication for the required UL allocation size. For example, if a UE is allocated with two resources for SR opportunities A and B, the UE may take one of the following optional steps; not to use either of the resources in cases where there is no uplink data to transmit; choose signal A only when there is a small sized uplink transmission such as a TCP Ack; choose signal B only when there is a medium-sized uplink transmission such as a periodic report; choose signals A and B when there is a large sized uplink transmission such as a video file upload. The small/medium/large transmissions are preconfigured or signalled by the eNB via System Information.

In other embodiments, the processing circuit 108 may allocate the spare PUCCH resource in such a way to ensure that there is no conflict between SR and Ack/Nack transmissions. In particular, the processing circuit 108 selects UL (Uplink) allocations and signalling of the UL allocation (to other UEs) in such way that the group index and sequence index that would be used for Ack/Nack on the PHICH will not collide with the PHICH resources already allocated for additional SR resources signalling. Further, the processing circuit 108 ensures that that DL (Downlink) allocation and signalling is done in such way that the calculated PUCCH resource to be used for

Ack/Nack for this transmission will not collide with the PUCCH resource intended to be used for additional SR transmission opportunity.

The signal processing functionality of the embodiments of the invention, particularly the processing circuit 108, 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.

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.

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.

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.

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.

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.

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.

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.

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.

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. 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 recognize 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.

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.

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.

Claims

1. A method for determining a Scheduling Request configuration for a wireless communication device located within an area of coverage of a cellular communication system comprising one or more cells, the method including: monitoring an uplink scheduling load attributable to one or more wireless communication devices located within the cellular communication system; identifying spare resources on an uplink channel within the cellular communication system; allocating at least a portion of the identified spare resources for additional Scheduling Request opportunities for the wireless communication devices; and transmitting information relating to the identified spare resources to one or more wireless communication devices located within the cellular communication system.

2. The method of claim 1 wherein the method is performed in an evolved Node B serving at least one cell of the cellular communication system and the cellular communication system is an LTE (Long Term Evolution) system.

3. The method of claim 1 or claim 2 wherein the identified spare resources are allocated to wireless communication devices on a priority basis.

4. The method of any preceding claim wherein the identified spare resources are spare PUCCH (Physical Uplink Control Channel) resources.

5. The method of claim 4 wherein identified spare PUCCH resources are allocated inwards from the edges of the system bandwidth.

6. The method of claim 4 wherein identified PUCCH resources are unused preconfigured PUCCH resources.

7. The method of any preceding claim wherein the information relating to the identified spare resources is transmitted to a wireless communication device using a PHICH (Physical Hybrid Activation Repeat Request Channel).

8. The method of any of claim 1 to 6 wherein the information relating to the identified spare resources is transmitted to a wireless communication device with Downlink Control information (DCI).

9. A processing circuit for use in a network element which supports at least one cell in a cellular communication system, the processing circuit being adapted to monitor an uplink scheduling load attributable to one or more wireless communication devices located within an area of coverage of the cellular communication system; identify spare resources on an uplink channel within the cellular communication system; allocate at least a portion of the identified spare resources for additional Scheduling Request opportunities for the wireless communication devices; and determine a Scheduling Request configuration including information relating to the identified spare resources for transmission to one or more wireless communication devices located within the cellular communication system.

10. A wireless communication device for use in a cellular communication system, wherein the wireless communication device is arranged to; establish a connection with a network element of the cellular communication system; receive an allocation of periodically-available resource for a Scheduling Request; receive an allocation of additional resource for a Scheduling Request opportunity; and if no periodically-available resource is currently available, transmit a Scheduling Request using an additional allocated resource.

11. The wireless communication device of claim 10 arranged to decode information relating to the allocation of additional resource received on a PHICH (Physical Hybrid Activation Repeat Request Channel).

12. The wireless communication device of claim 10 arranged to decode information relating to the allocation of additional resource received with DCI (Downlink Control Information).

13. The wireless communication device of any of claims 10 to 12 arranged to choose an additional allocated resource for a Scheduling Request depending on a size of a packet to be transmitted by the wireless communication device.

14. A tangible computer program product having executable program code stored thereon for executing a process to perform a method for determining a scheduling request configuration according to claim 1.

15. The tangible computer program product of claim 14 wherein the tangible computer program product comprises 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.

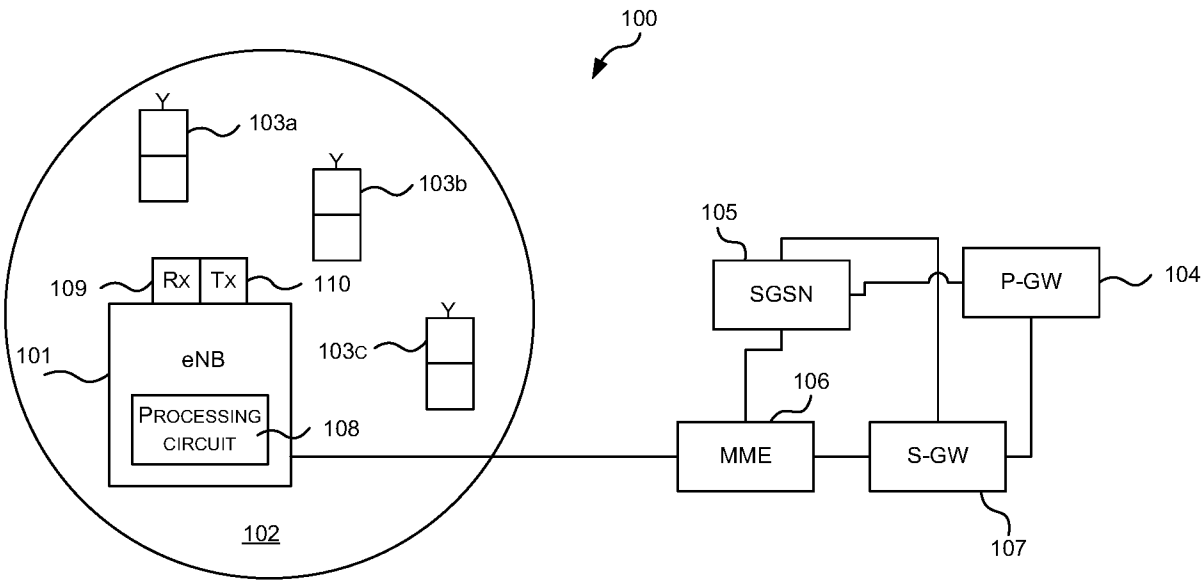

100
103a
103b
103c
109
Rx
Tx
110
101
eNB
Processing circuit
108
102
105
SGSN
P-GW
104
106
MME
S-GW
107

FIG. 1

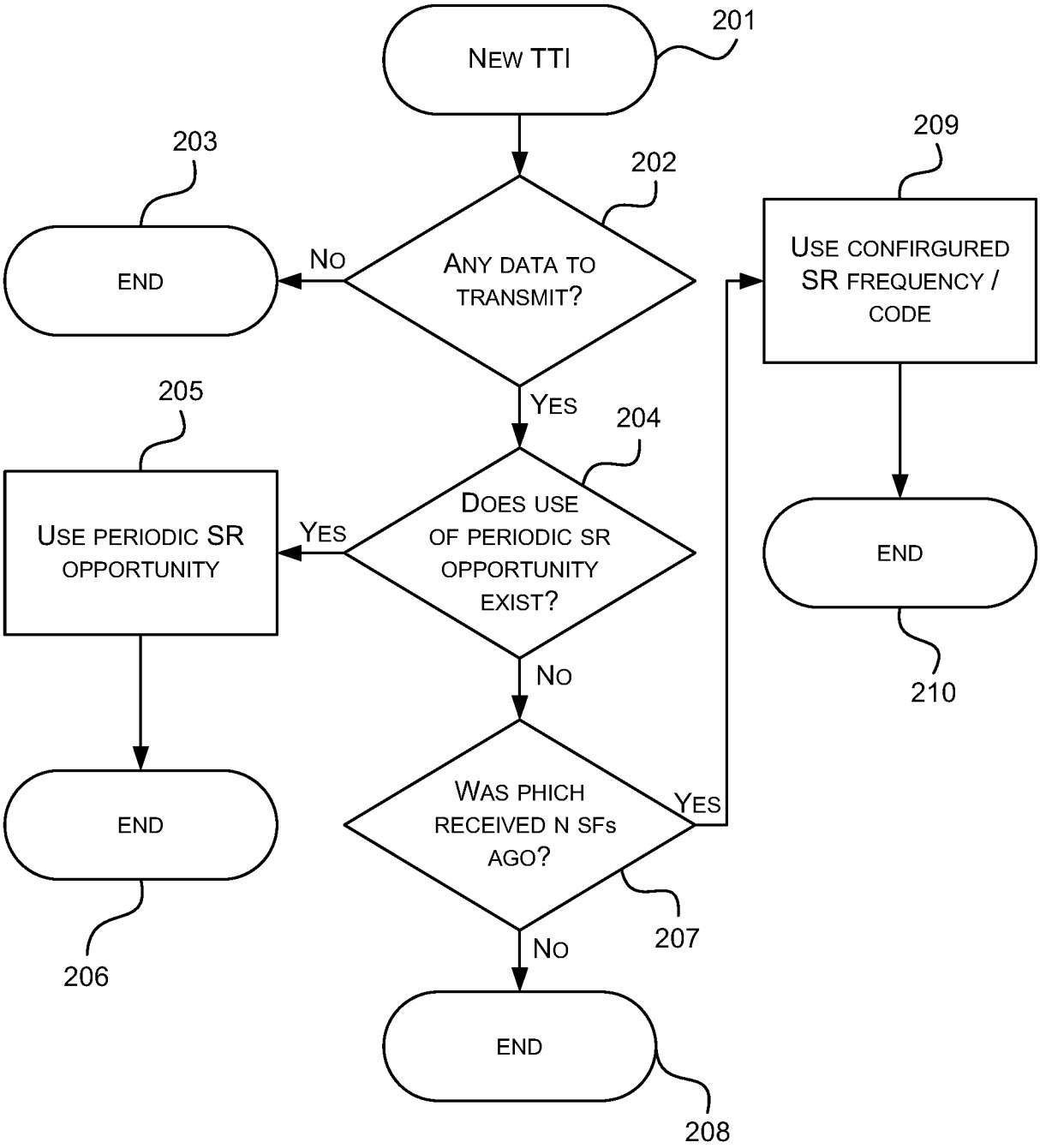

NEW TTI
201
ANY DATA TO TRANSMIT?
202
NO
END
203
YES
DOES USE OF PERIODIC SR OPPORTUNITY EXIST?
204
YES
USE PERIODIC SR OPPORTUNITY
205
END
206
NO
WAS PHICH RECEIVED N SFs AGO?
207
YES
NO
END
208
USE CONFIRGURED SR FREQUENCY / CODE
209
END
210

FIG. 2

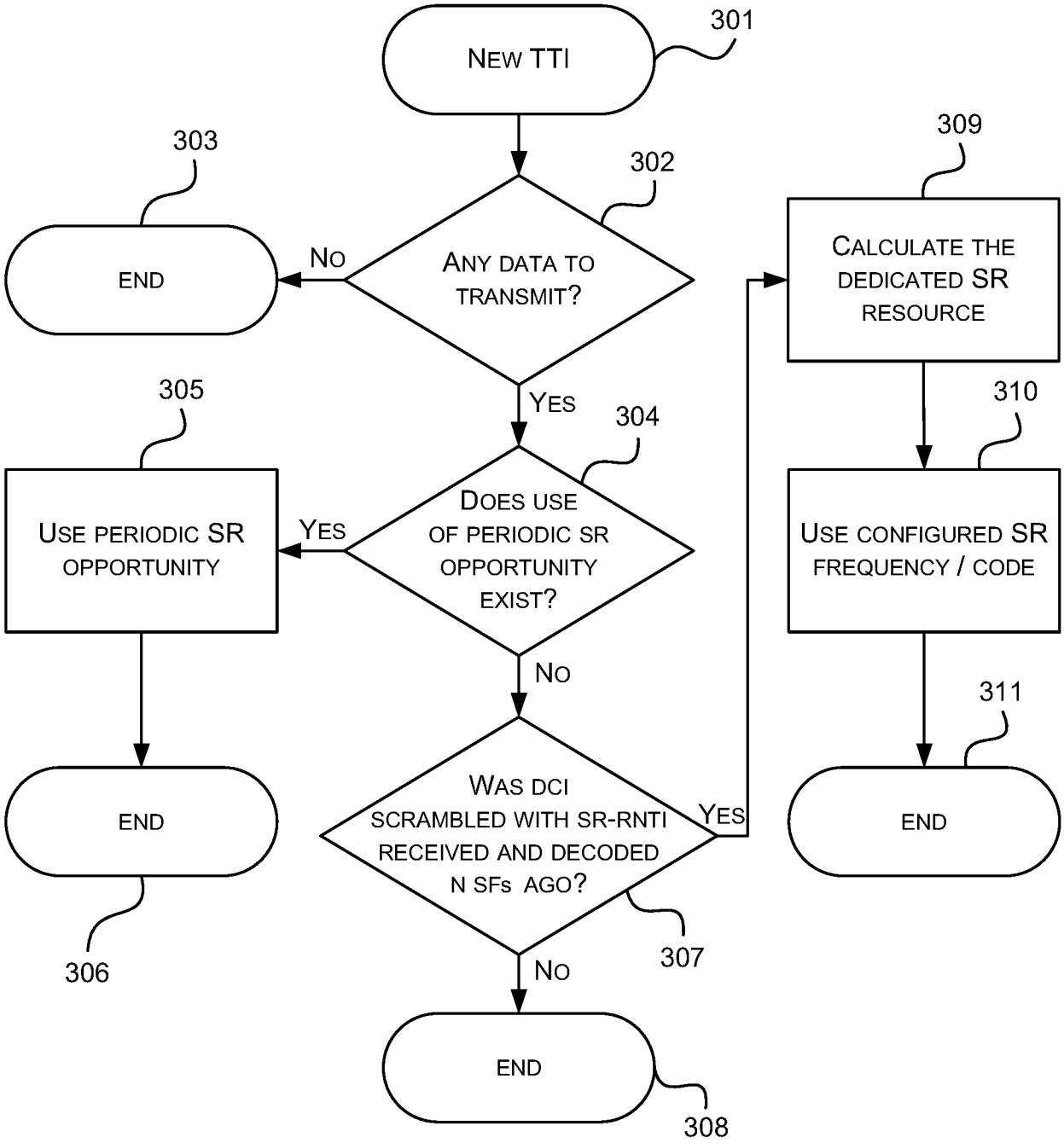

NEW TTI
301
ANY DATA TO TRANSMIT?
302
NO
END
303
YES
DOES USE OF PERIODIC SR OPPORTUNITY EXIST?
304
YES
USE PERIODIC SR OPPORTUNITY
305
END
306
NO
WAS DCI SCRAMBLED WITH SR-RNTI RECEIVED AND DECODED N SFs AGO?
307
YES
CALCULATE THE DEDICATED SR RESOURCE
309
USE CONFIGURED SR FREQUENCY / CODE
310
END
311
NO
END
308

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2016/104183

A. CLASSIFICATION OF SUBJECT MATTER

H04W 16/10(2009.01)i; H04W 76/06(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; H04Q; 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,GOOGLE: LTE, PUCCH, PHICH, DCI, scheduling request, SR, avaiable, usable, idle, spare, UE, base station, eNB, eNodeB, resource, period, allocate, additional, opportunity.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 103068047 A (POTEVIO INSTITUTE OF TECHNOLOGY CO., LTD.) 24 April 2013 (2013-04-24) description, paragraphs [0026]-[0036]	1-9, 11-15
Y	CN 103068047 A (POTEVIO INSTITUTE OF TECHNOLOGY CO., LTD.) 24 April 2013 (2013-04-24) description, paragraphs [0026]-[0036]	10
Y	CN 101640905 A (DATANG MOBILE COMMUNICATION EQUIPMENT CO., LTD) 03 February 2010 (2010-02-03) description, page 5, line 15 to page 6, line 12	10
A	CN 102238554 A (ZTE CORP.) 09 November 2011 (2011-11-09) the whole document	1-15
A	CN 102438319 A (CHINA ACADEMY OF TELECOMMUNICATIONS TECHNOLOGY) 02 May 2012 (2012-05-02) the whole document	1-15

☑ 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	Date of mailing of the international search report
04 January 2017	**25 January 2017**

Name and mailing address of the ISA/CN	Authorized officer
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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 104378830 A (POTEVIO INFORMATION TECHNOLOGY CO., LTD.) 25 February 2015 (2015-02-25) the whole document	1-15
A	CN 102612093 A (XI'AN JIAOTONG UNIVERSITY) 25 July 2012 (2012-07-25) the whole document	1-15
A	CATT. "Remaining issues on PUCCH for Rel-13 MTC UEs" *R1-156562,* 22 November 2015 (2015-11-22), the whole document	1-15

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2016/104183

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
CN 103068047 A	24 April 2013	None	
CN 101640905 A	03 February 2010	MX 2011001262 A	27 April 2011
		WO 2010012232 A1	04 February 2010
CN 102238554 A	09 November 2011	WO 2011137618 A1	10 November 2011
CN 102438319 A	02 May 2012	None	
CN 104378830 A	25 February 2015	None	
CN 102612093 A	25 July 2012	None	