

**METHOD AND APPARATUS TO LINK MODULATING AND CODING SCHEME
TO AMOUNT OF RESOURCES**

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Cross Reference to Related Applications

The present application claims priority to U.S. Provisional Application 61/125,961 filed on April 28, 2008. The present application also claims priority to U.S. Provisional Applications 61/048,554 and 61/048,908 both filed on April 29, 2008.

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Field of the Invention

The invention relates to the field of wireless telecommunications. More particularly, the present invention pertains to resource allocation in wireless telecommunications.

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Background of the Invention

The telecommunications industry is in the process of developing a new generation of flexible and affordable communications that includes high-speed access while also supporting broadband services. Many features of the third generation (3G) mobile telecommunications system have already been established, but many other features have yet to be perfected. The Third Generation Partnership Project (3GPP) has been pivotal in these developments.

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One of the systems within the third generation of mobile communications is the Universal Mobile Telecommunications System (UMTS) which delivers voice, data, multimedia, and wideband information to stationary as well as mobile customers. UMTS is designed to accommodate increased system capacity and data capability. Efficient use of the electromagnetic spectrum is vital in UMTS. It is known that spectrum efficiency can be attained using frequency division duplex (FDD) or using time division duplex (TDD) schemes. Space division duplex (SDD) is a third duplex transmission method used for wireless telecommunications.

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As can be seen in **FIG. 1**, the UMTS architecture consists of user equipment **102** (UE), the UMTS Terrestrial Radio Access Network **104** (UTRAN), and the Core Network **126** (CN). The air interface between the UTRAN and the UE is called Uu, and the interface between the UTRAN and the Core Network is called Iu.

5 High-Speed Downlink Packet Access (HSDPA) and High-Speed Uplink Packet Access (HSUPA) are further 3G mobile telephony protocols in the High-Speed Packet Access (HSPA) family. They provide a smooth evolutionary path for UMTS-based networks allowing for higher data transfer speeds.

10 Evolved UTRAN (EUTRAN) is a more recent project than HSPA, and is meant to take 3G even farther into the future. EUTRAN is designed to improve the UMTS mobile phone standard in order to cope with various anticipated requirements. EUTRAN is frequently indicated by the term Long Term Evolution (LTE), and is also associated with terms like System Architecture Evolution (SAE). One target of EUTRAN is to enable all internet protocol (IP) systems to efficiently transmit IP data. The system will have only use a
15 PS (packet switched) domain for voice and data calls, i.e. the system will contain Voice Over Internet Protocol (VoIP).

Information about LTE can be found in 3GPP TS 36.300 (V8.0.0, March 2007), *Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN) – Overall description; Stage 2 (Release 8)*, which is
20 incorporated herein by reference in its entirety. UTRAN and EUTRAN will now be described in some further detail, although it is to be understood that especially E-UTRAN is evolving over time.

The UTRAN consists of a set of Radio Network Subsystems **128** (RNS), each of which has geographic coverage of a number of cells **110** (C), as can be seen in **FIG. 1**. The
25 interface between the subsystems is called Iur. Each Radio Network Subsystem **128** (RNS) includes a Radio Network Controller **112** (RNC) and at least one Node B **114**, each Node B having geographic coverage of at least one cell **110**. As can be seen from Figure 1, the interface between an RNC **112** and a Node B **114** is called Iub, and the Iub is hard-wired

rather than being an air interface. For any Node B **114** there is only one RNC **112**. A Node B **114** is responsible for radio transmission and reception to and from the UE **102** (Node B antennas can typically be seen atop towers or preferably at less visible locations). The RNC **112** has overall control of the logical resources of each Node B **114** within the RNS **128**, and
5 the RNC **112** is also responsible for handover decisions which entail switching a call from one cell to another or between radio channels in the same cell.

In UMTS radio networks, a UE can support multiple applications of different qualities of service running simultaneously. In the MAC layer, multiple logical channels can be multiplexed to a single transport channel. The transport channel can define how traffic from
10 logical channels is processed and sent to the physical layer. The basic data unit exchanged between MAC and physical layer is called the Transport Block (TB). It is composed of an RLC PDU and a MAC header. During a period of time called the transmission time interval (TTI), several transport blocks and some other parameters are delivered to the physical layer.

Generally speaking, a prefix of the letter “E” in upper or lower case signifies the Long
15 Term Evolution (LTE). The E-UTRAN consists of eNBs (E-UTRAN Node B), providing the E-UTRA user plane (RLC/MAC/PHY) and control plane (RRC) protocol terminations towards the UE. The eNBs interface to the access gateway (aGW) via the S1, and are inter-connected via the X2.

An example of the E-UTRAN architecture is illustrated in **FIG. 2**. This example of
20 E-UTRAN consists of eNBs, providing the E-UTRA user plane (RLC/MAC/PHY) and control plane (RRC) protocol terminations towards the UE. The eNBs are connected by means of the S1 interface to the EPC (evolved packet core), which is made out of Mobility Management Entities (MMEs) and/or gateways such as an access gateway (aGW). The S1 interface supports a many-to-many relation between MMEs and eNBs. Packet Data
25 Convergence Protocol (PDCP) is located in an eNB.

In this example there exists an X2 interface between the eNBs that need to communicate with each other. For exceptional cases (e.g. inter-PLMN handover), LTE_ACTIVE inter-eNB mobility is supported by means of MME relocation via the S1

interface.

The eNB may host functions such as radio resource management (radio bearer control, radio admission control, connection mobility control, dynamic allocation of resources to UEs in both uplink and downlink), selection of a mobility management entity (MME) at UE attachment, scheduling and transmission of paging messages (originated from the MME), scheduling and transmission of broadcast information (originated from the MME or O&M), and measurement and measurement reporting configuration for mobility and scheduling. The MME may host functions such as the following: distribution of paging messages to the eNBs, security control, IP header compression and encryption of user data streams; termination of U-plane packets for paging reasons; switching of U-plane for support of UE mobility, idle state mobility control, System Architecture Evolution (SAE) bearer control, and ciphering and integrity protection of NAS signaling.

Incorporated herein in its entirety is TSG-RAN WG1 #50, R1-073842, Athens, Greece, August 20 – 24, 2007: “Notes from uplink control signaling discussions.” In RAN1 #50 held in Athens, many assumptions related to control signalling on PUSCH were agreed upon.

- Data and the different control fields (ACK/NACK, CQI/PMI) are mapped to separate modulation symbols. Here, ACK stands for acknowledgement, NACK stand for negative acknowledgement, and CQI stands for channel quality indicator.
- Different coding rates for control is achieved by occupying different number of symbols
- The coding rate to use for the control signalling is given by the PUSCH MCS. The relation is expressed in a table.
- A table links each PUSCH MCS with a given coding rate for control signalling, i.e., the number of symbols to use for an ACK/NAK or a certain CQI/PMI size.

Also incorporated by reference herein (in its entirety) is 3GPP TSG RAN WG1, Meeting #52bis, R1-081165 held in Shenzhen, China, 31 March – 4 April 2008. Also incorporated by reference herein (in its entirety) is 3GPP TSG RAN1#52-Bis, R1-081295, Shenzhen, China,

March 31 – April 4, 2008: “Resource Provision for UL Control in PUSCH.” The multiplexing described above was further sharpened in RAN1 #52bis:

- CQI/PMI on PUSCH uses the same modulation scheme as data on PUSCH
- Semi-statically configured offset between the data MCS and the code rate of

5 the control signaling is applied (A/N and CQI)

- Next steps: Define the offset values. Discuss whether multiple offsets are needed e.g. when multiple services with different Quality of Service (QoS) are time multiplexed.

10 The existing technology does not address how to link the PUSCH MCS and amount of resources for control on PUSCH, or how to guarantee sufficient quality for uplink (UL) control signals when multiplexed with UL data. There are certain issues which need to be taken into account when allocating resources for control signals:

1. Control channel quality

- 15
- ACK/NACK and CQI have tight requirements in terms of B(L)ER performance
 - Re-transmission cannot be applied with control signals due to delay requirements

2. Data dominance

- 20
- Data quality defines the operation point for MCS selection and PUSCH power control
 - Control channels must adapt into the given SINR operation point
 - Information about the symbol split between data and control must be pre-known at both ends of the radio link in order to perform correct rate matching/de-matching and encoding/decoding operations for different channels

3. Different B(L)ER operation point

- 25
- Data channel utilizes Hybrid Automatic Repeat Request (HARQ) and Link Adaptation (LA) whereas control signalling benefits neither from the fast link adaptation nor the HARQ
 - Channel coding

- Data channel has Turbo coding and much larger coding block size
- Control channel has relatively small code block size and smaller coding gain (ACK/NACK has only repetition coding)

5 There is essentially no prior art available for detailed solutions for the problem described above. R1-081295 presents a formula to determine the size of control region based on the data MCS level. However there are several disadvantages in the solution presented in R1-081295. For example:

- Useless term, K_c (can be combined with the offset parameter)
- 10 ▪ Useless function, $\log_2()$, (can be combined with the offset parameter)
- "Un-defined" relationship between Data MCS and size of the control channel
- No performance results are presented in R1-081295 to show the feasibility of this formula.

These disadvantages require solutions in order to adequately solve the problems described
15 above, and guarantee sufficient quality for UL control signals when multiplexed with UL data.

Summary of the Invention

The present invention is applicable in the context of the E-UTRAN (LTE or 3.9G).
20 However, its principles are not limited to such an environment, and instead may also be applicable to various other current and future wireless telecommunications systems and access technologies.

An embodiment of the present invention relates, for example, to the UL part of the UTRAN long term evolution (LTE) which is being specified in the 3GPP under the Rel. 8
25 Work Item, and also relates to resource allocation for non-data-associated control signals (such as ACK/NACK and CQI) transmitted with UL data on the PUSCH (Physical Uplink Shared Channel). Data non-associated control signalling can be multiplexed with UL data by means of time division multiplexing (TDM).

Included in the present invention is a method and apparatus for linkage between Physical Uplink Control Channel (PUSCH) Modulation and Coding Scheme (MCS) and amount of resources for control on PUSCH. According to certain embodiments of the present invention, a mechanism and/or formula are presented for scaling the amount of control
5 resources (CQI & ACK/NACK), allowing for flexible adaptation of the size of control region for controlling the quality of the control channel. This allows for the adaptation of quality of UL control signaling in order to meet target requirements.

Brief Description of the Drawings

10 Figure 1 shows a UTRAN network.

Figure 2 shows an LTE architecture.

Figure 3 shows input and output parameters of proposed resource allocation scheme.

Figure 4 shows four different embodiments of symbol space for discontinuous transmission (DTX) and ACK/NACK.

15 Figure 5 shows linkage between PUSCH MCS and amount of resources for control on PUSCH.

Figure 6 shows CQI/PMI on PUSCH using the same modulation scheme as data on PUSCH.

Figure 7 shows how amount of control resources vary according to the CQI quality
20 target.

Figure 8 shows different BW options performing almost equally.

Figure 9 shows the 2RB case which is the most important case with persistent allocation.

Figure 10 shows decisions regarding control signaling on PUSCH, and open issues.

25 Figure 11 shows a proposed scheme according to an embodiment of the present invention.

Figure 12 shows offset_dB with BW allocation.

Figure 13 is a BLER example.

Figure 14 shows numerical values for offset with BLER data less than 40%.

Figure 15 shows numerical values for offset with BLER data less than 50%.

Figure 16 shows numerical values for offset with BLER data less than 20%.

Figure 17 shows numerical values for offset with BLER data less than 20% and

5 BLER_CQI less than 10%.

Figure 18 is a summary of numerical values.

Figure 19 describes aspects of signaling.

Figure 20 lists observations.

Figure 21 describes improved DTX detection.

10 Figure 22 provides simulation assumptions.

Figure 23 shows control channel performance, 2RBs (short-term) with CQI BLER equal to 10%.

Figure 24 shows control channel performance, 2RBs (short-term) with CQI BLER equal to 5%.

15 Figure 25 shows control channel performance, 2RBs (short-term) with CQI BLER equal to 1%.

Figure 26 shows control channel performance (short-term) performance comparison for different PUSCH BW options.

Figure 27 shows control channel performance (long-term).

20 Figure 28 shows RAN1 Status.

Figure 29 shows a proposed formula to determine the size of control region based on data MCS.

Figure 30 shows offset_dB which compensates for the performance difference between the control and data channel.

25 Figure 31 shows size of the control channel (short term).

Figure 32 provides numerical values for offset (short term) with BLER data less than 20%.

Figure 33 shows numerical values for offset (short term) with BLER data less than

40%.

Figure 34 shows numerical values for offset (short term) with BLER data less than 50%.

Figure 35 shows numerical values for offset (short term) with BLER data less than 5 20%.

Figure 36 is a summary of numerical offset values, 2RBs (short term).

Figure 37 shows numerical values for offset, 2RBs (long term).

Figure 38 shows conclusions.

10 **Detailed Description of the Invention**

A preferred embodiment of the present invention will now be described. This is merely to illustrate one way of implementing the invention, without limiting the scope or coverage of what is described elsewhere in this application.

15 This embodiment of the invention provides a method and procedure to determine the size of the control signal region with a number of pre-defined input parameters. This embodiment of the invention contains an algorithm that utilizes those parameters as an input. The goal is to standardize the method and procedure such that both UE and eNodeB would utilize it.

Another topic covered by this embodiment is the arrangement supporting the 20 enhanced DTX detection of ACK/NACK at the eNB. This is achieved by means of special ACK/NACK dimensioning.

Generally speaking, a DTX situation relates to the failure of DL resource allocation grant. When DL resource allocation fails the ACK/NACK(s) associated with the PDCCH is missing from the given UL sub-frame because the UE has missed the DL allocation and 25 therefore has no reason to include an ACK/NACK. If existence of ACK/NACK is not signaled in UL grant, the Node B cannot know that the ACK/NACK is not present and may therefore interpret the reception incorrectly. The performance of reception could improved,

if the existence of A/N bit is signaled in UL PUSCH. In the context of this study, we refer to this signalling as DTX signaling.

The basic functionality for defining the size of a control region is illustrated in **FIG. 3**.

The proposed resource allocation scheme contains "semi-static" input parameters signalled via higher layers: offset_dB, which is the quality difference between the given control channel and PUSCH data channel; and N which is the number of control signaling bits (for the given control signaling type). The static input parameters (UL data MCS -specific) are: coding rate (CR) of given MCS of UL data channel (e.g., 3/1); and, Mmod (i.e., M_{mod}) which is the number of uncoded bits/symbol [2, 4 or 6 with QPSK, 16QAM, 64QAM] for the given UL data MCS. The output parameter, Mctrl (i.e., M_{ctrl}), is the number of control symbols/TTI for a certain number of control signaling bits (N).

Mctrl relates to a given modulation and coding scheme used in the UL. An algorithm to calculate Mctrl, can be illustrated as follows:

$$M_{ctrl} = \left\lceil \frac{N \cdot \frac{CR}{M_{Mod}}}{10^{\frac{-offset_dB}{10}}} \right\rceil$$

where the fraction in the numerator is the number of (coded) bits/resource element (i.e., symbol) for the given data MCS, and $\lceil \cdot \rceil$ is the ceil operation, which rounds the elements of the nearest integers, towards plus infinity. It should be noted that the term $\frac{CR}{M_{Mod}}$ can be also expressed using the following parameters:

- number of input bits K_{bits}^{PUSCH} (number of transmitted bits after code block segmentation)

- $M_{SC}^{PUSCH} \cdot N_{sym}^{PUSCH}$ (total number of sub-carriers per subframe carrying PUSCH multiplied by the number of SC-FDMA symbols carrying PUSCH)

This relationship can be expressed as:

$$\frac{CR}{M_{Mod}} = \frac{M_{SC}^{PUSCH} \cdot N_{sym}^{PUSCH}}{K_{bits}^{PUSCH}}$$

Improved DTX detection can be accomplished in a situation where the explicit DTX signaling (e.g., such as 1 bit included in UL grant) is not present. In these cases, it is possible to always reserve Mctrl symbols and transmit NACK or DTX using this symbol space.

However, the problem of this approach is the excessive control overhead.

One way to improve DTX detection is to define the control signaling size such that a certain number of ACK/NACK symbols are always reserved. The idea can be presented as follows:

$$M_{ctrl} = \max\left(\left\lceil \frac{N \cdot \frac{CR}{M_{Mod}}}{10^{\frac{-offset}{10}} dB} \right\rceil, K\right)$$

where K is a predetermined number, e.g., 8-10. This number is selected in such that it will provide sufficient DTX detection performance while maintaining reasonable control overhead. The procedure is such that in the case when ACK/NACK is present, then the number of A/N (i.e. ACK/NACK) symbols is calculated based e.g., on the equation above. In the case when ACK/NACK is absent, then K symbols are still reserved. In these cases, UE can signal either NACK or DTX. Benefit of this arrangement is that control overhead is reduced and, at the same time DTX performance is always guaranteed.

An embodiment of the present invention can be implemented by means of functionality shown in **FIG. 3**. In one of the preferred embodiments, both UE and eNB

contain the same functionality to define Mctrl. The method comprises: (1) eNB defines the offset_dB; (2) eNB signals offset_dB parameter to the UE; (3) UE calculates Mctrl and transmits the given control signalling type using Mctrl resource elements (symbols) located on a pre-determined places; (4) eNB calculates Mctrl and receives the given control signalling type using Mctrl resource elements (symbols) located on a pre-determined places.

In another embodiment, the offset_dB is defined separately for different PUSCH bandwidths (or preferably for a group PUSCH bandwidths). An example of this is shown as follows (two groups):

- offset_dB_1 for $BW < K$ RBs (K is a pre-determined number, e.g., 5)
- offset_dB_2 for $BW = K$ RBs

In yet another embodiment, the offset_dB parameter is defined separately for different MCSs (or preferably a group of MCSs). An example of this is shown below (two groups):

- offset_dB_1 for QPSK
- offset_dB_2 for 16QAM and 64QAM

In yet another embodiment, the offset_dB parameter is defined separately for different service types

- offset_dB_1 for delay critical services
- offset_dB_2 for delay non-critical data (low HARQ operation point)

In yet another embodiment, the offset_dB parameter is defined separately for different control channels

- offset_dB_1 for ACK/NACK (N=1 or 2 bits)
- offset_dB_2 for CQI, N=5 bits
- offset_dB_3 for CQI, N=100 bits

In yet another embodiment, a safety margin of X dB is applied on top of the offset_dB -parameter.

With regard to signalling, an offset_dB -parameter is signaled via higher layers (e.g., RRC signaling). An (initial) offset_dB related to ACK/NACK can be part of broadcast

signaling. Persistent UEs (i.e., those having no dynamical UL grant available) can have offset_dB parameter included in the resource allocation grant

With regard to definition of offset_dB-value, an embodiment of the present invention includes a method wherein the offset_dB is defined according to the following procedure:

- 5 Block Error Ratio (BLER) of UL data channel (w/o HARQ) is limited into a certain number (e.g., 40%); BLER of control channel is limited into a certain number (e.g., 10%); find an offset_dB value which satisfies the quality criteria, which is an initial value for the offset_dB -parameter (may depend also on the operation environment such as channel profile, UE speed) and can be tabulated as a default offset_dB parameter at the NB; and increase/decrease
- 10 the offset_dB value based on the measured data/control quality.

Various modifications can be made regarding the DTX issue, while remaining within the scope of the present invention. Now, two novel embodiments will be described; let us call them Option 1 and Option 2.

- 15 If no ACK/NACK to be signaled on PUSCH, then Option 1 involves always reserving K symbols. However, Option 2 involves always reserving L1 symbols, L1 depending upon the data MCS and another offset_dB -parameter (offset_DTX_dB).

$$L1 = \left\lceil \frac{N \cdot \frac{CR}{M_{Mod}}}{10^{\frac{-offset_DTX_dB}{10}}} \right\rceil$$

- 20 If ACK/NACK is to be signaled on PUSCH, then Option 1 involves using L2 symbols to signal A/N. Alternatively, Option 2 involves reserving L3 symbols to signal A/N, or using Mctrl symbols to signal A/N.

$$L2 = \max(M_{ctrl}, K)$$

$$L3 = \max(M_{ctrl}, L1)$$

A further embodiment of the invention is one where DTX and ACK/NACK share an overlapping symbol space. ACK/NACK can utilize different symbol space than DTX, as shown in **FIG. 4A**. Or, DTX/NACK can utilize the same symbol space, as shown in **FIG.**

5 **4B**.

Another embodiment of the invention is one where DTX and ACK/NACK have non-overlapping symbol space. ACK/NACK can then utilize different symbol space than DTX, as shown in **FIG. 4C**. DTX/NACK can utilize the same symbol space, while ACK utilizes different symbol space, as shown in **FIG. 4D**.

10 If DTX and ACK/NACK have non-overlapping symbol space, DTX can be signaled simultaneously with A/N. Alternatively, DTX is not signaled in the case when A/N is transmitted.

The present invention provides a robust scheme to size the control channel for PUSCH. The method is applicable for both non-persistent and persistent cases. The method is applicable for all kind of control signals (ACK/NACK and CQI). The scheme works in different operation points and in different PUSCH bandwidths. The signaling need is minimized, and DTX detection is improved with reduced overhead.

15 The invention includes a variety of concepts, some of which can be briefly described as follows. It is to be understood that the following concepts can be further combined with each other in any multiple dependent manner, without departing from the scope of the invention.

20 An embodiment of the present invention includes a first concept which is a method comprising: providing a plurality of substantially static input parameters; providing a plurality of signalled input parameters; and determining from said substantially static input parameters and said plurality of signalled input parameters an output parameter indicative of a number of control symbols per transmission time interval for an amount of control signalling bits, wherein said output parameter relates to a modulation and coding scheme for an uplink.

An embodiment of the present invention includes a second concept, which is the first concept wherein said determining of the output parameter employs a ceil operation on a quantity that includes a product of a number of control signalling bits multiplied by a coding rate divided by a number of uncoded bits per symbol.

5 An embodiment of the present invention includes a third concept, which is the second concept wherein said number of control signalling bits is one of said signalled input parameters.

 An embodiment of the present invention includes a fourth concept which is an apparatus comprising: means for providing a plurality of substantially static input parameters;
10 means for providing a plurality of signalled input parameters; and means for determining from said substantially static input parameters and said plurality of signalled input parameters an output parameter indicative of a number of control symbols per transmission time interval for an amount of control signalling bits, wherein said output parameter relates to a modulation and coding scheme for an uplink.

15 An embodiment of the present invention includes a fifth concept, which is the fourth concept wherein said means for determining of the output parameter employs a ceil operation on a quantity that includes a product of a number of control signalling bits multiplied by a coding rate divided by a number of uncoded bits per symbol.

 An embodiment of the present invention includes a sixth concept, which is the fifth
20 concept wherein said number of control signalling bits is one of said signalled input parameters.

 An embodiment of the present invention includes a seventh concept which is an apparatus comprising: an uplinking module configured to provide a plurality of substantially static input parameters; a layer configured to provide a plurality of signalled input parameters;
25 and a processor configured to determine from said substantially static input parameters and said plurality of signalled input parameters an output parameter indicative of a number of control symbols per transmission time interval for an amount of control signalling bits, wherein said output parameter relates to a modulation and coding scheme for an uplink.

An embodiment of the present invention includes an eighth concept, which is the seventh concept wherein said processor employs a ceil operation on a quantity that includes a product of a number of control signalling bits multiplied by a coding rate divided by a number of uncoded bits per symbol.

5 An embodiment of the present invention includes a ninth concept, which is the eighth concept wherein said number of control signalling bits is one of said signalled input parameters.

10 An embodiment of the present invention includes a tenth concept which is a computer program product comprising a computer readable medium having executable code stored therein; the code, when executed by a processor, adapted to carryout: providing a plurality of substantially static input parameters; providing a plurality of signalled input parameters; and determining from said substantially static input parameters and said plurality of signalled input parameters an output parameter indicative of a number of control symbols per transmission time interval for an amount of control signalling bits, wherein said output
15 parameter relates to a modulation and coding scheme for an uplink.

 An embodiment of the present invention includes an eleventh concept, which is the tenth concept wherein said determining of the output parameter employs a ceil operation on a quantity that includes a product of a number of control signalling bits multiplied by a coding rate divided by a number of uncoded bits per symbol.

20 An embodiment of the present invention includes a twelfth concept, which is the eleventh concept wherein said number of control signalling bits is one of said signalled input parameters.

 Additional embodiments of the present invention include one wherein CR is iteratively calculated, based on the actual coding rate, including the impact of control signals and possible sounding reference signal (i.e. not based on CR of MCS). Still a further
25 embodiment is one wherein CR is based on the nominal coding rate, not including the impact of control signals and possible sounding reference signal. Yet another embodiment is one wherein ACK/NACK and CQI have different dynamic range for *offset_{dB}* parameter.

And, the present invention also encompasses an embodiment wherein the relation of signalling and the following term is tabulated in a predetermined way (i.e. not signalling the *offset_dB* directly):

$$10^{\frac{-offset_dB}{10}}$$

Regarding linkage between PUSCH MCS and amount of resources for control on PUSCH, in RAN1 #50 held in Athens many assumptions related to control signaling on PUSCH were agreed, as described in TSG-RAN WG1 #50, R1-073842 (described and incorporated by reference above):

- Data and the different control fields (ACK/NAK, CQI/PMI) are mapped to separate modulation symbols
- Different coding rates for control is achieved by occupying different number of symbols
- The coding rate to use for the control signaling is given by the PUSCH MCS. The relation is expressed in a table.

In RAN1 #52bis (described and incorporated by reference above), some further details were agreed upon:

- CQI/PMI on PUSCH uses the same modulation scheme as data on PUSCH
- Semi-statically configured offset between the data MCS and the code rate of the control signaling (A/N and CQI)

Here, a formula is proposed to determine the size of control region based on data MCS. Also presented here is a numerical value set for the offset parameter. These values can be used to design the higher layer signaling needed to configure the offset parameter.

The proposed formula contains the following semi-static input parameters signalled via higher layers:

- *offset_dB* performance difference between the given control channel and PUSCH data channel (in dB)
- *N*: number of control signaling bits (for the given control signaling type)

The UL data MCS -related input parameters known in advance are:

- CR : Coding rate of given PUSCH MCS (e.g., 3/1)
- M_{Mod} : Number of (uncoded) bits/symbol of PUSCH MCS, [2, 4 or 6] with QPSK, 16QAM, 64QAM.

M_{ctrl} is the number of control symbols/TTI and it is calculated as follows:

$$M_{ctrl} = \left\lceil \frac{N \cdot \frac{CR}{M_{Mod}}}{10^{\frac{-offset_dB}{10}}} \right\rceil,$$

where $\lceil \cdot \rceil$ rounds the control channel size to the nearest supported integer value, towards (plus) infinity. The supported integers are based on the coding/repetition/puncturing assumptions made for given control signaling on PUSCH. It is also noted that due to implementation reasons it may be better to tabulate the relation of *offset_dB* signaling and

term $10^{\frac{-offset_dB}{10}}$, instead of signaling the *offset_dB* directly.

The offset parameter depends on the BLER operation point of PUSCH data and CQI. It is assumed here that *offset_dB* parameter is signaled via RRC signaling. Notice the following:

- a common *offset_dB* parameter for all the PUSCH MCSs is sufficient
- a common *offset_dB* parameter for different bandwidth options is sufficient. Persistent scheduling requiring bandwidth dependent *offset_dB* -parameter is a special case since the adaptive transmission bandwidth is not used with the persistent scheduling.

Table 1 shows simulated/optimized values for the *offset_dB* parameter. We note that different *offset_dB* parameter is needed for ACK/NACK and different CQI sizes. Numerical values presented in Table 1 can be used to estimate the number of bits needed to configure the *offset_dB* -parameter. Based on these results, in order to minimize the control overhead, we propose that

- *offset_dB* parameter related to A/N signaling is configured using 3 bits (around 6.5 dB)
- *offset_dB* parameter related to CQI signaling is configured using 4-5 bits (around 1.5 dB)

Periodic CQI and scheduled CQI may require their own *offset_dB* -parameter.

When signaling ACK/NACK on PUSCH, an important issue that needs to be taken into account is the DTX-to-ACK problem. Results in Table 1 assume that UE has the knowledge about the presence of ACK/NACK on PUSCH. However, if no information about the presence of ACK/NACK is available, then the number of ACK/NACK symbols needed
5 must be heavily over dimensioned. It is also noted that different formula may be need for ACK/NACK and CQI in the case when UE has no knowledge about the presence of ACK/NACK on PUSCH.

**Table 1. Numerical values for *offset_dB* -parameter, non-persistent scheduling, 2RBs,
TU channel, v=3 km/h**

Offset (dB)								
QoS			N					
Data BLER	CQI BLER	A/N BER	1	5	10	30	60	90
50%	5%	0.1%	7.0	2.0	1.9	1.4	1.3	1.3
40%	1%	0.1%	6.8	2.5	3.1	2.2	2.2	2.2
40%	5%	0.1%	6.8	1.8	1.6	1.2	1.2	1.2
30%	10%	0.1%	6.8	1.1	1.1	0.8	0.8	0.8
20%	5%	0.1%	6.5	1.5	1.5	1.0	1.0	1.0
20%	1%	0.1%	6.3	2.7	2.5	1.5	1.5	1.5
20%	5%	0.1%	6.3	1.2	1.2	0.8	0.8	0.8
20%	10%	0.1%	6.3	0.5	0.5	0.4	0.4	0.4
10%	1%	10.0%	5.8	2.4	2.2	1.3	1.3	1.3

Among other things, this embodiment of the present invention provides a detailed formula to determine the size of control region based on data MCS. It is also proposed that this formula be used as a method to size the control channel on PUSCH. The proposed formula minimizes the signaling burden and keeps the control channel quality at the target level. Furthermore, it can be applied for both persistently and dynamically scheduled data and for all kind of control types such as ACK/NACK and CQI.

Table 2. Numerical non-quantized values for M_{ctrl} parameter, $N=30$, $offset_dB$ varies between 0 dB and 3 dB

Data MCS	CR	N $offset_dB$ M_{mod}	30						
			0.00	0.50	1.00	1.50	2.00	2.50	3.00
			M_{ctrl}						
QPSK 1/10	10.0	2	150.0	168.3	188.8	211.9	237.7	266.7	299.3
QPSK 1/6	6.0	2	90.0	101.0	113.3	127.1	142.6	160.0	179.6
QPSK 1/4	4.0	2	60.0	67.3	75.5	84.8	95.1	106.7	119.7
QPSK 1/3	3.0	2	45.0	50.5	56.7	63.6	71.3	80.0	89.8
QPSK 1/2	2.0	2	30.0	33.7	37.8	42.4	47.5	53.3	59.9
QPSK 2/3	1.5	2	22.5	25.2	28.3	31.8	35.7	40.0	44.9
QPSK 3/4	1.3	2	20.0	22.4	25.2	28.3	31.7	35.6	39.9
16QAM 1/2	2.0	4	15.0	16.8	18.9	21.2	23.8	26.7	29.9
16QAM 2/3	1.5	4	11.3	12.6	14.2	15.9	17.8	20.0	22.4
16QAM 3/4	1.3	4	10.0	11.2	12.6	14.1	15.8	17.8	20.0
16QAM 5/6	1.2	4	9.0	10.1	11.3	12.7	14.3	16.0	18.0
64QAM 1/2	2.0	6	10.0	11.2	12.6	14.1	15.8	17.8	20.0
64QAM 2/3	1.5	6	7.5	8.4	9.4	10.6	11.9	13.3	15.0
64QAM 3/4	1.3	6	6.7	7.5	8.4	9.4	10.6	11.9	13.3
64QAM 5/6	1.2	6	6.0	6.7	7.6	8.5	9.5	10.7	12.0

Each of the embodiments described above can be implemented using a general purpose or specific-use computer system, with standard operating system software conforming to the method described herein. The software is designed to drive the operation of the particular hardware of the system, and will be compatible with other system components and I/O controllers. The computer system of this embodiment includes a CPU processor, comprising a single processing unit, multiple processing units capable of parallel operation, or the CPU can be distributed across one or more processing units in one or more locations, e.g., on a client and server. A memory may comprise any known type of data storage and/or transmission media, including magnetic media, optical media, random access memory (RAM), read-only memory (ROM), a data cache, a data object, etc. Moreover, similar to the CPU, the memory may reside at a single physical location, comprising one or more types of data storage, or be distributed across a plurality of physical systems in various forms.

It is to be understood that the present figures, and the accompanying narrative discussions of best mode embodiments, do not purport to be completely rigorous treatments

of the method, system, mobile device, network element, and software product under consideration. A person skilled in the art will understand that the steps and signals of the present application represent general cause-and-effect relationships that do not exclude intermediate interactions of various types, and will further understand that the various steps
5 and structures described in this application can be implemented by a variety of different sequences and configurations, using various different combinations of hardware and software which need not be further detailed herein.

WHAT IS CLAIMED IS:

1. A method comprising:
providing a plurality of substantially static input parameters;
5 providing a plurality of signaled input parameters; and
determining from said substantially static input parameters and said plurality of
signalled input parameters an output parameter indicative of a number of control symbols per
transmission time interval for an amount of control signaling bits,
wherein said output parameter relates to a physical resource with given modulation
10 and coding scheme for an uplink.
2. The method of claim 1, wherein said determining of the output parameter employs a
ceil operation on a quantity that includes a product of a number of control signalling
bits multiplied by a coding rate divided by a number of uncoded bits per symbol.
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3. The method of claim 2, wherein said number of control signaling bits is one of said
signalled input parameters.
4. The method of claim 2, wherein said substantially static input parameters include a
20 quality difference between a control channel and a physical uplink data channel.
5. The method of claim 4, wherein instead of signaling said quality difference directly, a
relation is tabulated of the quality difference and a term in said quantity.
- 25 6. The method of claim 2, wherein said quality difference comprises at least one offset
parameter.

7. The method of claim 1, wherein an offset describing a quality difference between a control and data channel is one of said signaled input parameters.
8. The method of claim 1, wherein a coding rate divided by a number of uncoded bits per symbol is obtained from a resource allocation of uplink data channel.
9. The method of claim 1, wherein a different offset parameter is used for acknowledgement and for channel quality indicator.
10. The method of claim 1, wherein an uplink data channel is punctured according to said number of control symbols.
11. An apparatus comprising:
 - means for providing a plurality of substantially static input parameters;
 - means for providing a plurality of signalled input parameters; and
 - means for determining from said substantially static input parameters and said plurality of signalled input parameters an output parameter indicative of a number of control symbols per transmission time interval for an amount of control signalling bits, wherein said output parameter relates to a modulation and coding scheme for an uplink.
12. The apparatus of claim 11, wherein said means for determining of the output parameter employs a ceil operation on a quantity that includes a product of a number of control signalling bits multiplied by a coding rate divided by a number of uncoded bits per symbol.
13. The apparatus of claim 12, wherein said number of control signalling bits is one of said signalled input parameters.

14. The apparatus of claim 12, wherein said substantially static input parameters include a quality difference between a control channel and a physical uplink data channel.

5 15. The apparatus of claim 14, wherein instead of signaling said quality difference directly, a relation is tabulated of the quality difference and a term in said quantity.

16. The apparatus of claim 12, wherein said quality difference comprises at least one offset parameter.

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17. An apparatus comprising:

an uplinking module configured to provide a plurality of substantially static input parameters; a layer configured to provide a plurality of signalled input parameters; and

15 a processor configured to determine from said substantially static input parameters and said plurality of signalled input parameters an output parameter indicative of a number of control symbols per transmission time interval for an amount of control signalling bits, wherein said output parameter relates to a modulation and coding scheme for an uplink.

20 18. The apparatus of claim 17, wherein said processor employs a ceil operation on a quantity that includes a product of a number of control signalling bits multiplied by a coding rate divided by a number of uncoded bits per symbol.

25 19. The apparatus of claim 18, wherein said number of control signalling bits is one of said signalled input parameters.

20. The apparatus of claim 18, wherein said substantially static input parameters include a quality difference between a control channel and a physical uplink data channel.

21. The apparatus of claim 20, wherein instead of signaling said quality difference directly, a relation is tabulated of the quality difference and a term in said quantity.

5 22. The apparatus of claim 18, wherein said quality difference comprises at least one offset parameter.

23. A computer program product comprising a computer readable medium having executable code stored therein; the code, when executed by a processor, adapted to carry out:
10 providing a plurality of substantially static input parameters;
providing a plurality of signalled input parameters; and
determining from said substantially static input parameters and said plurality of signalled input parameters an output parameter indicative of a number of control symbols per transmission time interval for an amount of control signalling bits,
15 wherein said output parameter relates to a modulation and coding scheme for an uplink.

24. The computer program product of claim 23, wherein said determining of the output parameter employs a ceil operation on a quantity that includes a product of a number of
20 control signalling bits multiplied by a coding rate divided by a number of uncoded bits per symbol.

25. The computer program product of claim 24, wherein said number of control signalling bits is one of said signalled input parameters.

25 26. The computer program product of claim 24, wherein said substantially static input parameters include a quality difference between a control channel and a physical uplink data channel.

27. The computer program product of claim 26, wherein instead of signaling said quality difference directly, a relation is tabulated of the quality difference and a term in said quantity.

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28. The computer program product of claim 24, wherein said quality difference comprises at least one offset parameter.