METHOD FOR MAPPING MODULATION SYMBOLS ONTO RESOURCE UNITS OF ALLOCATED SUBFRAME

[Technical Field]

The present invention generally relates to the field of uplink radio communication and, more particularly, a method and a user equipment (UE) for modulation symbol mapping. More particularly still, example aspects herein relate to method(s) and a user equipment (UE) for mapping channel quality information, CQI, modulation symbols and a plurality of Physical Uplink Shared Channel, PUSCH, modulation symbols onto a subframe having a first slot and a second slot for transmission on at least one unlicensed carrier.

[Background]

Originally, LTE was designed for licensed spectra where an operator may have an exclusive license for a certain frequency range. A licensed spectrum offers benefits since the operator may plan the network and control interference situations, but there is typically a cost associated with obtaining the spectrum license and the amount of licensed spectra is limited.

Unlicensed spectra, on the other hand, are open for anyone to use at no cost, subject to a set of rules, for example on maximum transmission power. Since anyone can use the spectra, the interference situation is typically much more unpredictable than for licensed spectra. Consequently, quality-of-service and availability cannot be guaranteed. Furthermore, the maximum transmission power is modest, typically, making it unsuitable for wide-area coverage. Wi-Fi and Bluetooth are two examples of communication systems exploiting unlicensed spectra in the lower-frequency range: 2.4 GHz or 5 GHz.

Therefore, in order to provide spectrum flexibility the evolution of LTE has extended the operation of mobile-communication networks into

Fig.s 3(a) and 3(b) are schematic illustrations showing how an entire code block CB#2 may not be transmitted in a case where the UCI and code blocks are mapped according to the conventional approach of Fig. 2 and transmission starts from a second candidate starting point 24.

In particular, Fig. 3(a) shows a situation in which, during an observation slot 13, it is determined that the channel is available. In this example, a CCA mechanism is used so transmission of the first slot 21 begins at the first candidate starting point 23 without a random back-off period. However, as shown in Fig. 3(b), in a case where it is determined that the channel is not available during observation slot 13, data mapped to the first slot 21 is not transmitted. Even if, in a subsequent observation slot (not shown) it is determined that the channel is available and transmission begins (only) at the second candidate starting period 24, transmission will start only from the second slot 22. As a result, data mapped to the first slot will not be transmitted.

As noted above, all the user data of the third PUSCH CB CB#2 would be mapped to the first slot 21. Therefore, the entire third PUSCH CB CB#2 will not be received and decoded. As many widely used coding strategies, such as turbo coding, require all the CBs are correctly decoded so that the whole TB may pass the cyclic redundancy check, it is likely that the non-transmission of one CB will prevent the entire TB from being decoded correctly by the receiving device. While the example of Fig.s 2, 3(a) and 3(b) illustrate this issue in relation to a TB segmented into multiple CBs, this issue may also arise where the TB comprises a single CB.

As such there is a need in the art to develop better mapping methods.

[Solution]

The present invention provides a method and a user equipment (UE) for modulation symbol mapping

for the case that one PUSCH TB includes multiple CBs. Those enhanced mapping mechanisms therefore solve the above technical problem in the conventional systems.

In particular, in view of the limitations discussed above, the present inventors have devised a method for modulation symbol mapping. The method comprises the steps of mapping the CQI modulation symbols onto the resource units of the second slot of the allocated subframe, wherein the CQI modulation symbols are mapped from the first resource unit of the second slot in a time-first mapping; and mapping the PUSCH modulation symbols onto the resource units of both the first and second slot of the allocated subframe, wherein the PUSCH modulation symbols are mapped from the first resource unit of the first slot in a time-first mapping.

The present inventors have also devised a computer program comprising instructions, which, when executed by a mobile computing device, cause the mobile computing device to perform the above method.

The present inventors have also devised a non-transitory computer-readable storage medium storing the above computer program.

The present inventors have also devised a signal carrying the above computer program.

The present inventors have also devised a user equipment, UE, for a radio communications system. The user equipment comprises a memory, and a processor. The memory stores one or more computer programs that, when executed by the processor, cause the processor to execute operations in accordance with the above method.

The present inventors have also devised a user equipment, UE, for modulation symbol mapping. The user equipment comprises a transmitting/receiving section, a memory, and a control section. The control section is configured to map the CQI modulation symbols onto resource units of the second slot of the allocated subframe, wherein the CQI modulation symbols are mapped from the first resource unit of the second slot in a time-first mapping; and map the PUSCH modulation symbols onto the resource units of both the first and second slot of the allocated subframe, wherein the PUSCH modulation symbols are mapped from the first resource unit of the first slot in a time-first mapping.

[Brief Description of the Drawings]

Embodiments of the invention will now be explained in detail, by way of non-limiting example only, with reference to the accompanying figures, described below. Like reference numerals appearing in different ones of the figures can denote identical or functionally similar elements, unless indicated otherwise.

Fig. 1 is a schematic illustration showing how a listen-before-talk mechanism may be performed, according to an example aspect herein.

Fig. 2 is a schematic illustration showing how CQI modulation symbols and PUSCH modulation symbols may be mapped onto resource units of an allocated subframe having a first and second slot for transmission on at least one unlicensed carrier, according to a conventional approach.

Fig.s 3(a) and 3(b) are schematic illustrations showing how an entire code block of the PUSCH may not be transmitted in a case where the

UCI and code blocks are mapped according to the conventional approach of Fig. 2 and transmission starts from a second candidate starting point.

Fig. 4 is a schematic illustration of radio communications system, according to an example aspect herein.

Fig. 5 is a flow diagram illustrating a method for modulation symbol mapping, according to an example aspect herein.

Fig.s 6(a) to 6(d) are schematic illustrations showing a method for modulation symbol mapping, according to example aspects herein.

Fig. 7 is a block diagram illustrating an example signal processing hardware configuration of the user equipment 100 of Fig. 4, according to an example aspect herein.

Fig. 8 is a block diagram illustrating an example signal processing hardware configuration of the radio base station 200 of Fig. 4, according to an example aspect herein.

[Detailed Description of Embodiments]

Example embodiments of the present invention will now be described in detail with reference to the accompanying drawings.

Where technical features in the drawings, detailed description or any claim are followed by reference signs, the reference signs have been included for the sole purpose of increasing the intelligibility of the drawings, detailed description, and claims. Accordingly, neither

higher layer signaling. Furthermore, the radio base station 200 may be configured to transmit information indicative of the first time-first mapping and the second time-first mapping to be used in mapping to all UEs in the cell 300 or the radio base station 200 may be configured to transmit information indicative of different respective first and second time-first mappings to be used in mapping to each UE in the cell 300.

By way of alternative, the radio base station 200 and the UE 100 may determine the mapping to be used by the UE 100 in any suitable manner known to those skilled in the art.

The control section 110 and transmitting/receiving section 120 may be configured to perform any further processing necessary for transmission of the CQI modulation symbols and PUSCH modulation symbols, including, for example, those discussed above in relation to Fig. 2. The transmitting/receiving section 120 may, as in the present embodiment, be configured to transmit the CQI modulation symbols and PUSCH modulation symbols on the PUSCH after they have been mapped to the subframe 20.

The memory 130 may be configured to store the UCI and user data prior to processing this information, as well as to store CQI coded bits and PUSCH coded bits and/or CQI modulation symbols and PUSCH modulation symbols prior to transmission. The memory 130 may be further configured to store computer instructions which, when executed by the control section, cause the control section to operate as described above.

Fig. 5 is a flow diagram illustrating a method for modulation symbol mapping, according to an example aspect herein.

computing device comprising a processor and a memory, wherein the memory is configured to store instructions which, when executed by the processor, cause the processor to perform the process of Fig. 5.

Fig.s 6(a) to 6(d) are schematic illustrations showing a method for modulation symbol mapping, according to an example aspects herein.

The PUSCH modulation symbols may, as in the embodiments of Fig.s 6(a) to 6(d), form a plurality of CBs CB#0, CB#1, CB#2 of one TB. However, this is not limiting and the coded bits may form a single CB of one TB or be organised in any other suitable manner known in the art.

The subframe 20 may be represented by a matrix of resource units, as shown in the embodiments of Fig.s 6(a) to 6(d), corresponding to a part of an uplink resource grid comprising time and frequency resources which may be allocated to uplink transmission. As an example, the subframe 20 may, as in the embodiments of Fig.s 6(a) to 6(d), be a subframe comprising two slots 21 and 22, each of which comprises 7 symbols in time domain and 10 subcarriers or resource elements in the frequency domain.

Alternatively, the subframe may be a subframe of any telecommunications standard, including - but not limited to -LTE, LTE-A, UMTS, 3G, 4G, 5G. By way of further alternative, the subframe 20 may comprise three or more slots. Furthermore, in some embodiments, each of the slots may comprise 2, 4, 7, 14, or any other suitable number of symbols in time domain and/or each of the slots may comprise 12, 24, or any other suitable number of subcarriers or resource elements in the frequency domain.

The mapping may, as in the embodiments of Fig.s 6(a) to 6(d), comprise mapping the CQI modulation symbols 26 and the PUSCH modulation symbols onto resource units corresponding to resource

Claims

1. A method for modulation symbol mapping, the method comprising:
   - mapping a channel quality information, CQI, modulation symbols onto resource units of the second slot of an allocated subframe, wherein the CQI modulation symbols are mapped from the first resource unit of the second slot in a time-first mapping; and
   - mapping a Physical Uplink Shared Channel, PUSCH, modulation symbols onto resource units of both the first and second slot of the allocated subframe, wherein the PUSCH modulation symbols are mapped from the first resource unit of the first slot in a time-first mapping.
2. The method of claim 1, wherein the PUSCH modulation symbols are mapped from a first resource unit of the first slot in a time-first mapping while skipping the resource units used for the CQI mapping.
3. The method of claim 1 or claim 2, wherein the CQI modulation symbols are mapped in a time-first mapping which first follows a time direction of the second slot and then follows a frequency direction of allocated frequency resource of the allocated subframe.
4. The method of any one of claims 1 to 3, wherein the PUSCH modulation symbols are mapped in a time-first mapping which first follows a time direction of both the first and second slot and then follows a frequency direction of the allocated frequency resource of the allocated subframe.
5. The method of any one of claims 1 to 4, further comprising:
   - calculating an amount of resource units for the CQI modulation symbols.
6. The method of claim 5, wherein the CQI modulation symbols are mapped onto the resource units of the second slot of the allocated subframe with an amount of mapped resource units equals to the amount of the calculated resource units.
7. The method of any one of claims 1 to 6, wherein the PUSCH modulation symbols formed by concatenation of the modulation

symbols of one or more code blocks, CBs, of one transport block, TB.

8. A method for modulation symbol mapping, the method comprising:

- mapping a channel quality information, CQI, modulation symbols onto resource units of the second slot of an allocated subframe, wherein the CQI modulation symbols are mapped from a first resource unit of the second slot in a time-first mapping; and
- mapping a Physical Uplink Shared Channel, PUSCH, modulation symbols onto resource units of both the first and second slot of the allocated subframe, wherein the PUSCH modulation symbols formed by modulation symbols of one or more CBs of one TB, and an amount of the resource units for mapping the modulation symbols of each CB of the PUSCH are the same or almost the same; and/or, an amount of resource units on the first slot and that on the second slot for mapping the modulation symbols of each CB of the PUSCH are the same or almost the same.

9. The method of claim 8, wherein for the modulation symbols of one or more CBs of the PUSCH,

- the modulation symbols of each CB are mapped in a time-first mapping which first follows a time direction of the second slot and then follows a frequency direction of the allocated frequency resource of the allocated subframe;
- and then the remaining modulation symbols of each CB are mapped in a time-first mapping which first follows a time direction of the first slot and then follows a frequency direction of the allocated frequency resource of the allocated subframe.

10. The method of claim 8 or 9, further comprising:

- performing listen before talk, LBT, in respect of a frequency channel prior to a first candidate starting point for transmission;
- transmitting said allocated subframe from the first candidate starting point, in a case where it is determined that the channel is available; and

- in a case where it is determined that the channel is unavailable, performing listen before talk, LBT, in respect of the frequency channel prior to a second candidate starting point for transmission and, in a case where it is determined that the channel is available, transmitting said allocated subframe from the second candidate starting point.

11. The method of claim 10, wherein the first candidate starting point for transmission is located at a boundary of the first slot in the time domain and the second candidate starting point for transmission is located at a boundary of the second slot in the time domain.

12. The method of claim 10, wherein the first candidate starting point for transmission is not located at a boundary of the first slot in the time domain and the second candidate starting point for transmission is not located at a boundary of the second slot in the time domain.

13. A computer program comprising instructions, which, when executed by a mobile computing device, cause the mobile computing device to perform the method of any one of claims 1 – 12.

14. A non-transitory computer-readable storage medium storing a computer program in accordance with claim 13.

15. A signal carrying a computer program in accordance with claim 13.

16. A user equipment, UE, for a radio communications system, the user equipment comprising:

- a memory; and
- a processor,
- wherein the memory stores one or more computer programs that, when executed by the processor, cause the processor to execute operations in accordance with any one of claims 1 – 12.

17. A user equipment, UE, for modulation symbol mapping, the user equipment comprising:

- a transmitting/receiving section;
- a memory; and
- a control section,
- wherein the control section is configured to map a channel quality information, CQI,modulation symbols onto resource

units of the second slot of an allocated subframe, wherein the CQI modulation symbols are mapped from the first resource unit of the second slot in a time-first mapping; and map a Physical Uplink Shared Channel, PUSCH,modulation symbols onto the resource units of both the first and second slot of the allocated subframe, wherein the PUSCH modulation symbols are mapped from the first resource unit of the first slot in a time-first mapping.

18. The UE of claim 17, wherein the control section is configured to perform the mapping of the PUSCH modulation symbols from a first resource unit of the first slot in a time-first mapping while skipping the resource units used for the CQI mapping.

19. The UE of claim 17 or claim 18, wherein the control section is configured to perform the mapping of the CQI modulation symbols in a time-first mapping which first follows a time direction of the second slot and then follows a frequency direction of allocated frequency resource of the allocated subframe.

20. The UE of any one of claims 17 - 19, wherein the control section is configured to perform the mapping of the PUSCH modulation symbols in a time-first mapping which first follows a time direction of both the first and second slot and then follows a frequency direction of the allocated frequency resource of the allocated subframe.

21. The UE of any one of claims 17 – 20, wherein the control section is configured to calculate an amount of resource units for the CQI modulation symbols.

22. The UE of claim 21, wherein the control section is configured to map the CQI modulation symbols onto the resource units of the second slot of the allocated subframe with an amount of mapped resource units equals to the amount of the calculated resource units.

23. The UE of any one of claims 17 - 22, wherein the PUSCH modulation symbols formed by concatenation of the modulation symbols of one or more code blocks, CBs, of one transport block, TB.

24. A user equipment, UE, for modulation symbol mapping, the user equipment comprising:

- a transmitting/receiving section;
- a memory; and
- a control section,
- wherein the control section is configured to map a channel quality information, CQI,modulation symbols onto resource units of the second slot of an allocated subframe, wherein the CQI modulation symbols are mapped from a first resource unit of the second slot in a time-first mapping; and map a Physical Uplink Shared Channel, PUSCH,modulation symbols onto resource units of both the first and second slot of the allocated subframe, wherein the PUSCH modulation symbols formed by modulation symbols of one or more CBs of one TB, and an amount of the resource units for mapping the modulation symbols of each CB of the PUSCH are the same or almost the same; and/or, an amount of resource units on the first slot and that on the second slot for mapping the modulation symbols of each CB of the PUSCH are the same or almost the same.

25. The UE of claim 24, wherein the control section is configured to, for the modulation symbols of one or more CBs of the PUSCH:

- map the modulation symbols of each CB in a time-first mapping which first follows a time direction of the second slot and then follows a frequency direction of the allocated frequency resource of the allocated subframe; and
- then map the remaining modulation symbols of each CB in a time-first mapping which first follows a time direction of the first slot and then follows a frequency direction of the allocated frequency resource of the allocated subframe.

26. The UE of any one of claims 17 - 25, wherein:

- the control section is further configured to perform listen before talk, LBT, in respect of a frequency channel prior to a first candidate starting point for transmission;
- the transmitting/receiving section is configured to transmit said allocated subframe from the first candidate starting

point, in a case where the control section determines that the channel is available; and

- in a case where the control section determines that the channel is unavailable, the control section is further configured to perform listen before talk, LBT, in respect of the frequency channel prior to a second candidate starting point for transmission and, in a case where the control section determines that the channel is available, the transmitting/receiving section is further configured to transmit said allocated subframe from the second candidate starting point.

27. The UE of claim 26, wherein the first candidate starting point for transmission is located at a boundary of the first slot in the time domain and the second candidate starting point for transmission is located at a boundary of the second slot in the time domain.

28. The UE of claim 26, wherein the first candidate starting point for transmission is not located at a boundary of the first slot in the time domain and the second candidate starting point for transmission is not located at a boundary of the second slot in the time domain.