Claims:

1. A method in an apparatus for receiving downlink control information (DCI), the method comprising:

receiving, by the apparatus, a first stage DCI in a physical downlink control channel (PDCCH);

decoding, by the apparatus, the first stage DCI in physical downlink control channel (PDCCH), the first stage DCI explicitly indicating a scheduling information of a second stage DCI;

receiving, by the apparatus, the second stage DCI in a first physical downlink shared channel (PDSCH);

decoding, by the apparatus, the second stage DCI in the first PDSCH;

wherein the first PDSCH is a physical channel without data transmission;

wherein the first stage DCI further indicates modulation order of the second stage DCI.

2. The method of claim 1, wherein the scheduling information of the second stage DCI comprises parameters of at least one of a time domain resource, a frequency domain resource, a spatial domain resource of the second stage DCI.

3. The method of any one of claims 1 to 2, wherein the first stage DCI further indicates at least one of the following:

coding rate of the second stage DCI; and

partial or full scheduling information for a data channel transmission.

4. The method of any one of claims 1 to 3, wherein the second stage DCI indicates at least one of the following:

scheduling information for one PDSCH;

scheduling information for multiple PDSCH;

scheduling information for one PUSCH;

scheduling information for multiple PUSCH;

scheduling information for one PDSCH and one PUSCH;

scheduling information for one PDSCH and multiple PUSCH;

scheduling information for multiple PDSCH and one PUSCH;

scheduling information for multiple PDSCH and multiple PDSCH;

scheduling information for sidelink;

partial scheduling information for at least one PUSCH and/or at least one PDSCH, wherein the partial scheduling information is an update to scheduling information in the first stage DCI;

partial scheduling information for at least one PUSCH and/or at least one PDSCH , wherein remaining scheduling information for the at least one PUSCH and/or at least one PDSCH is included in the first stage DCI;

configuration information related to an artificial intelligence (AI)/machine learning (ML) function; and

configuration information related to a non-AI/ML function.

5. The method of any one of claims 1 to 4, wherein the apparatus received the first stage DCI and the second stage DCI in time division multiplexed or frequency division multiplexed or time division multiplexed and frequency division multiplexed.

6. The method of any one of claims 1 to 5, further comprising:

receiving downlink data using PDSCH resources indicated by scheduling information in the second stage DCI;

wherein the scheduling information indicated in the first stage DCI comprises values from a first set of values for scheduling parameters, the scheduling information in the second stage DCI comprises values from a second set of values for scheduling parameters, and the first set of values and the second set of values is separately predefined or configured for indicating one or more of:

whether retransmission is enabled;

inclusion of retransmission related parameters;

modulation order options;

coding rate options;

options for number of transport blocks;

options for number of MIMO layers;

options for time/frequency domain resource allocation types, and/or locations.

7. The method of any one of claims 1 to 6, wherein the first stage DCI and the second stage DCI are received in a first carrier; or

the first stage DCI is received in a first carrier and the second stage DCI is received in a second carrier different from the first carrier.

8. The method of any one of claims 1 to 7, wherein the second stage DCI comprises scheduling information for multiple carriers.

9. The method of any one of claims 1 to 8, wherein the second stage DCI comprises:

an indication of whether there is scheduling information for each of N carriers;

scheduling information for each of N carriers when the indication indicates there is scheduling information for each of N carriers; where $N \geq 2$.

10. A method in a network element for transmitting downlink control information (DCI), the method comprising:

transmitting, by the network element, a first stage DCI in a physical downlink control channel (PDCCH), the first stage DCI explicitly indicating a scheduling information of a second stage DCI;

transmitting, by the network element, the second stage DCI in a first physical downlink shared channel (PDSCH);

wherein the first PDSCH is a physical channel without data transmission;

wherein the first stage DCI further indicates modulation order of the second stage DCI.

11. The method of claim 10, wherein the scheduling information of the second stage DCI comprises parameters of at least one of a time domain resource, a frequency domain resource, a spatial domain resource of the second stage DCI.

12. The method of any one of claims 10 to 11, wherein the first stage DCI further indicates at least one of the following:

coding rate of the second stage DCI; and

partial or full scheduling information for a data channel transmission.

13. The method of any one of claims 10 to 12, wherein the second stage DCI indicates at least one of the following:

scheduling information for one PDSCH;

scheduling information for multiple PDSCH;

scheduling information for one PUSCH;

scheduling information for multiple PUSCH;

scheduling information for one PDSCH and one PUSCH;

scheduling information for one PDSCH and multiple PUSCH;

scheduling information for multiple PDSCH and one PUSCH;

scheduling information for multiple PDSCH and multiple PDSCH;

scheduling information for sidelink;

partial scheduling information for at least one PUSCH and/or at least one PDSCH, wherein the partial scheduling information is an update to scheduling information in the first stage DCI;

partial scheduling information for at least one PUSCH and/or at least one PDSCH, wherein remaining scheduling information for the at least one PUSCH and/or at least one PDSCH is included in the first stage DCI;

configuration information related to an artificial intelligence (AI)/machine learning (ML) function; and

configuration information related to a non-AI/ML function.

14. The method of any one of claims 10 to 13, wherein the network element transmits the first stage DCI and the second stage DCI in time division multiplexed or frequency division multiplexed or time division multiplexed and frequency division multiplexed.

15. The method of any one of claims 10 to 14, further comprising:

transmitting downlink data using PDSCH resources indicated by scheduling information in the second stage DCI;

wherein the scheduling information indicated in the first stage DCI comprises values from a first set of values for scheduling parameters, the scheduling information in the second stage DCI comprises values from a second set of values for scheduling parameters, and the first set of values and the second

set of values is separately predefined or configured for indicating one or more of:

whether retransmission is enabled;

inclusion of retransmission related parameters;

modulation order options;

coding rate options;

options for number of transport blocks;

options for number of MIMO layers;

options for time/frequency domain resource allocation types, and/or locations.

16. The method of any one of claims 10 to 15, wherein the first stage DCI and the second stage DCI are transmitted in a first carrier; or

the first stage DCI is transmitted in a first carrier and the second stage DCI is transmitted in a second carrier different from the first carrier.

17. The method of claim any one of claims 10 to 16, wherein the second stage DCI comprises scheduling information for multiple carriers.

18. The method of claim any one of claims 10 to 17, wherein the second stage DCI comprises, for each of N carriers, where $N \geq 2$:

an indication of whether there is scheduling information for the carrier;

scheduling information for the carrier when the indication indicates there is scheduling information for the carrier.

19. An apparatus comprising:

at least one processor; and

a computer readable storage medium operatively coupled to the at least one processor, the computer readable storage medium storing programming for execution by the at least one processor, the programming comprising instructions to:

receive a first stage DCI in a physical downlink control channel (PDCCH);

decode the first stage DCI in physical downlink control channel (PDCCH), the first stage DCI explicitly indicating a scheduling information of a second stage DCI;

receive the second stage DCI in a first physical downlink shared channel (PDSCH);

decode the second stage DCI in the first PDSCH;

wherein the first PDSCH is a physical channel without data transmission;

wherein the first stage DCI further indicates modulation order of the second stage DCI.

20. The apparatus of claim 19, wherein the scheduling information of the second stage DCI comprises parameters of at least one of a time domain resource, a frequency domain resource, a spatial domain resource of the second stage DCI.

21. The apparatus of any one of claims 19 to 20, wherein the first stage DCI further indicates at least one of the following:

coding rate of the second stage DCI; and

partial or full scheduling information for a data channel transmission.

22. The apparatus of any one of claims 19 to 21, wherein the second stage DCI indicates at least one of the following:

scheduling information for one PDSCH;

scheduling information for multiple PDSCH;

scheduling information for one PUSCH;

scheduling information for multiple PUSCH;

scheduling information for one PDSCH and one PUSCH;

scheduling information for one PDSCH and multiple PUSCH;

scheduling information for multiple PDSCH and one PUSCH;

scheduling information for multiple PDSCH and multiple PDSCH;

scheduling information for sidelink;

partial scheduling information for at least one PUSCH and/or at least one PDSCH, wherein the partial scheduling information is an update to scheduling information in the first stage DCI;

partial scheduling information for at least one PUSCH and/or at least one PDSCH , wherein remaining scheduling information for the at least one PUSCH and/or at least one PDSCH is included in the first stage DCI;

configuration information related to an artificial intelligence (AI)/machine learning (ML) function; and

configuration information related to a non-AI/ML function.

23. The apparatus of any one of claims 19 to 22, wherein the programming comprises instructions to receive the first stage DCI and the second stage DCI in time division multiplexed or frequency division multiplexed or time division multiplexed and frequency division multiplexed.

24. The apparatus of any one of claims 19 to 23, wherein the programming comprises instructions to:

receive downlink data using PDSCH resources indicated by scheduling information in the second stage DCI;

wherein the scheduling information indicated in the first stage DCI comprises values from a first set of values for scheduling parameters, the scheduling information in the second stage DCI comprises values from a second set of values for scheduling parameters, and the first set of values and the second set of values is separately predefined or configured for indicating one or more of:

whether retransmission is enabled;

inclusion of retransmission related parameters;

modulation order options;

coding rate options;

options for number of transport blocks;

options for number of MIMO layers;

options for time/frequency domain resource allocation types, and/or locations.

25. The apparatus of any one of claims 19 to 24, wherein the first stage DCI and the second stage DCI are received in a first carrier; or

the first stage DCI is received in a first carrier and the second stage DCI is received in a second carrier different from the first carrier.

26. The apparatus of any one of claims 19 to 25, wherein the second stage DCI comprises scheduling information for multiple carriers.

27. The apparatus of any one of claims 19 to 26, wherein the second stage DCI comprises:

an indication of whether there is scheduling information for each of N carriers;

scheduling information for each of N carriers when the indication indicates there is scheduling information for each of N carriers; where N≥2.

28. A network element comprising:

at least one processor; and

a computer readable storage medium operatively coupled to the at least one processor, the computer readable storage medium storing programming for execution by the at least one processor, the programming comprising instructions to:

transmit a first stage DCI in a physical downlink control channel (PDCCH), the first stage DCI explicitly indicating a scheduling information of a second stage DCI;

transmit the second stage DCI in a first physical downlink shared channel (PDSCH);

wherein the first PDSCH is a physical channel without data transmission;

wherein the first stage DCI further indicates modulation order of the second stage DCI.

29. The network device of claim 28, wherein the scheduling information of the second stage DCI comprises parameters of at least one of a time domain resource, a frequency domain resource, a spatial domain resource of the second stage DCI.

30. The network device of any one of claims 28 to 29, wherein the first stage DCI further indicates at least one of the following:

coding rate of the second stage DCI; and

partial or full scheduling information for a data channel transmission.

31. The network device of any one of claims 28 to 30, wherein the second stage DCI indicates at least one of the following:

scheduling information for one PDSCH;

scheduling information for multiple PDSCH;

scheduling information for one PUSCH;

scheduling information for multiple PUSCH;

scheduling information for one PDSCH and one PUSCH;

scheduling information for one PDSCH and multiple PUSCH;

scheduling information for multiple PDSCH and one PUSCH;

scheduling information for multiple PDSCH and multiple PDSCH;

scheduling information for sidelink;

partial scheduling information for at least one PUSCH and/or at least one PDSCH, wherein the partial scheduling information is an update to scheduling information in the first stage DCI;

partial scheduling information for at least one PUSCH and/or at least one PDSCH , wherein remaining scheduling information for the at least one PUSCH and/or at least one PDSCH is included in the first stage DCI;

configuration information related to an artificial intelligence (AI)/machine learning (ML) function; and

configuration information related to a non-AI/ML function.

32. The network device of any one of claims 28 to 31, wherein the programming comprises instructions to transmit the first stage DCI and the second stage DCI in time division multiplexed or frequency division multiplexed or time division multiplexed and frequency division multiplexed.

33. The network device of any one of claims 28 to 32, wherein the programming comprises instructions to transmit downlink data using PDSCH resources indicated by scheduling information in the second stage DCI;

wherein the scheduling information indicated in the first stage DCI comprises values from a first set of values for scheduling parameters, the scheduling information in the second stage DCI comprises values from a second set of values for scheduling parameters, and the first set of values and the second set of values is separately predefined or configured for indicating one or more of:

whether retransmission is enabled;

inclusion of retransmission related parameters;

modulation order options;

coding rate options;

options for number of transport blocks;

options for number of MIMO layers;

options for time/frequency domain resource allocation types, and/or locations.

34. The network device of any one of claims 28 to 33, wherein the first stage DCI and the second stage DCI are transmitted in a first carrier; or

the first stage DCI is transmitted in a first carrier and the second stage DCI is transmitted in a second carrier different from the first carrier.

35. The network device of claim any one of claims 28 to 34, wherein the second stage DCI comprises scheduling information for multiple carriers.

36. The network device of claim any one of claims 28 to 35, wherein the second stage DCI comprises, for each of N carriers, where $N \geq 2$:

an indication of whether there is scheduling information for the carrier;

scheduling information for the carrier when the indication indicates there is scheduling information for the carrier.