CLAIMS

1. A method of performing a random access procedure in a wireless communication network, the method comprising: receiving, by a base station (BS) from a user equipment (UE), a plurality of random access preambles from a plurality of beam directions, wherein each of the plurality of random access preambles is received from a different beam direction, and wherein the plurality of random access preambles are associated with multiple random access opportunities of a random access attempt; and sending, by the BS in response to the plurality of random access preambles, a plurality of random access response (RAR) messages in the plurality of beam directions by time-multiplexing a first RAR message of the plurality of RAR messages in a first beam direction of the plurality of beam directions with a second RAR message of the plurality of RAR messages in a second beam direction of the plurality of beam directions within a subframe, wherein the second beam direction is different from the first beam direction, and wherein each of the first RAR message and the second RAR message includes at least one orthogonal frequency division multiplexing (OFDM) symbol within the subframe, wherein the sending the plurality of RAR messages includes: sending, in the subframe, first control information and first data of the first RAR message in the first beam direction; and sending, in the same subframe after sending the first control information and the first data, second control information and second data of the second RAR message in the second beam direction, or wherein the sending the plurality of RAR messages includes: sending, in the subframe, first control information of the first RAR message in the first beam direction; sending, in the same subframe after sending the first control information, second control information of the second RAR message in the second beam direction; sending, in the same subframe after sending the second control information, first data of the first RAR message in the first beam direction; and sending, in the same subframe after sending the first data, second data of the second RAR message in the second beam direction.

2. The method of claim 1, wherein the sending the plurality of RAR messages includes: sending, in the subframe, the first control information and the first data of the first RAR message in the first beam direction; and sending, in the same subframe after sending the first control information and the first data, the second control information and the second data of the second RAR message in the second beam direction.

3. The method of claim 1, wherein the sending the plurality of RAR messages includes: sending, in the subframe, the first control information of the first RAR message in the first beam direction; sending, in the same subframe after sending the first control information, the second control information of the second RAR message in the second beam direction; sending, in the same subframe after sending the second control information, the first data of the first RAR message in the first beam direction; and sending, in the same subframe after sending the first data, the second data of the second RAR message in the second beam direction.

4. The method of claim 1, further comprising sending, by the BS, a rule for transmissions of multiple rando access preambles using multiple random access opportunities in different beam directions per random access attempt.

5. The method of claim 1, further comprising sending, by the BS, one or more downlink beams carrying a transmission configuration in at least the plurality of beam directions, wherein the transmission configuration indicates information associated with a random access message transmission time interval spanning less than a system nominal subframe.

6. The method of claim 5, wherein the transmission configuration further indicates a reference numerology that defines the system nominal subframe, and wherein the reference numerology includes a tone spacing and at least one of a number of symbols or a symbol duration.

7. A method of performing a random access procedure in a wireless communication network, the method comprising: sending, by a user equipment (UE) to a base station (BS), a plurality of random access preambles in a plurality of beam directions, wherein each of the plurality of random access preambles is transmitted in a different beam direction, and wherein the plurality of random access preambles are associated with multiple random access opportunities of a random access attempt; and receiving, by the UE from the BS in response to at least a first random access preamble of the plurality of random access preambles, a first random access response (RAR) message in a first beam direction of the plurality of beam directions, wherein the first RAR message in the first beam direction is time-multiplexed with a second RAR message in a second beam direction of the plurality of beam directions within a subframe, wherein the second beam direction is different from the first beam direction, and wherein each of the first RAR message and the second RAR message includes at least one orthogonal frequency division multiplexing (OFDM) symbol within the subframe, wherein the receiving the one or more RAR messages comprises: receiving, in the subframe, first control information and first data of the first RAR message in the first beam direction; and receiving, in the same subframe after receiving the first control information and the first data, second control information and second data of the second RAR message in the second beam direction, or wherein the receiving the one or more RAR messages comprises: receiving, in the subframe, first control information of the first RAR message in the first beam direction; receiving, in the same subframe after receiving the first control information, second control information of the second RAR message in the second beam direction; receiving, in the same subframe after receiving the second control information, first data of the first RAR message in the first beam direction; and receiving, in the same subframe after receiving the first data, second data of the second RAR message in the second beam direction.

8. The method of claim 7, wherein each RAR message spans at least a mini-slot including at least one OFDM symbol.

9. The method of claim 7, wherein the receiving the one or more RAR messages comprises: receiving, in the subframe, the first control information and the first data of the first RAR message in the first beam direction; and receiving, in the same subframe after receiving the first control information and the first data, the second control information and the second data of the second RAR message in the second beam direction.

10. The method of claim 7, wherein the receiving the one or more RAR messages includes: receiving, in the subframe, the first control information of the first RAR message in the first beam direction; receiving, in the same subframe after receiving the first control information, the second control information of the second RAR message in the second beam direction; receiving, in the same subframe after receiving the second control information, the first data of the first RAR message in the first beam direction; and receiving, in the same subframe after receiving the first data, the second data of the second RAR message in the second beam direction.

11. The method of claim 7, further comprising: receiving, by the UE from the BS, a rule for transmitting multiple random access preambles using multiple random access opportunities in different beam directions per random access attempt prior to RAR message monitoring; and determining, by the UE, whether the UE satisfies the rule, wherein the plurality of random access preambles are transmitted when the UE is determined to satisfy the rule.

12. The method of claim 7, further comprising: monitoring, by the UE, for the first RAR message in the first beam direction; and monitoring, by the UE, for the second RAR message in the second beam direction.

13. The method of claim 7, further comprising: determining, by the UE, whether the first beam direction has a higher reception quality than the second beam direction; and monitoring for the first RAR message in the first beam direction in a RAR window associated with the first RAR message when the first beam direction is determined to have the higher reception quality than the second beam direction.

14. The method of claim 7, further comprising configuring a beam in at least the first beam direction and the second beam direction to monitor for the first RAR message and the second RAR message.

15. The method of claim 7, further comprising receiving, by the UE from the BS, a transmission configuration indicating information associated with a random access message transmission time interval that is less than a system nominal subframe.

16. An apparatus comprising: a receiver configured to receive, from a wireless communication

device, a plurality of random access preambles from a plurality of beam directions, wherein each of the plurality of random access preambles is received from a different beam direction, and wherein the plurality of random access preambles are associated with multiple random access opportunities of a random access attempt; and a transmitter configured to send, in response to the plurality of random access preambles, a plurality of random access response (RAR) messages in the plurality of beam directions by time-multiplexing a first RAR message of the plurality of RAR messages in a first beam direction of the plurality of beam directions with a second RAR message of the plurality of RAR messages in a second beam direction of the plurality of beam directions within a subframe, wherein the second beam direction is different from the first beam direction, and wherein each of the first RAR message and the second RAR message includes at least one orthogonal frequency division multiplexing (OFDM) symbol within the subframe, wherein the transmitter is configured to send the plurality of RAR messages by: sending, in the subframe, first control information and first data of the first RAR message in the first beam direction; and sending, in the same subframe after sending the first control information and the first data, second control information and second data of the second RAR message in the second beam direction, or wherein the transmitter is configured to send the plurality of RAR messages by: sending, in the subframe, first control information of the first RAR message in the first beam direction; sending, in the same subframe after sending the first control information, second control information of the second RAR message in the second beam direction; sending, in the same subframe after sending the second control information, first data of the first RAR message in the first beam direction; and sending, in the same subframe after sending the first data, second data of the second RAR message in the second beam direction.

17. The apparatus of claim 16, wherein the transmitter is configured to send the plurality of RAR messages by: sending, in the subframe, the first control information and the first data of the first RAR message in the first beam direction; and sending, in the same subframe after sending the first control information and the first data, the second control information and the second data of the second RAR message in the second beam direction.

18. The apparatus of claim 16, wherein the transmitter is configured to send the plurality of RAR messages by: sending, in the subframe, the first control information of the first RAR message in the first beam direction; sending, in the same subframe after sending the first control information, the second control information of the second RAR message in the second beam direction; sending, in the same subframe after sending the second control information, the first data of the first RAR message in the first beam direction; and sending, in the same subframe after sending the first data, the second data of the second RAR message in the second beam direction.

19. The apparatus of claim 16, wherein the transmitter is further configured to send a rule for transmissions of multiple random access preambles using multiple random access opportunities

in different beam directions per random access attempt.

20. The apparatus of claim 16, wherein the transmitter is further configured to send one or more downlink beams carrying a transmission configuration in at least the plurality of beam directions, and wherein the transmission configuration indicates information associated with a random access message transmission time interval spanning less than a system nominal subframe.

21. The apparatus of claim 20, wherein the transmission configuration further indicates a reference numerology that defines the system nominal subframe, and wherein the reference numerology includes a tone spacing and at least one of a number of symbols or a symbol duration.

22. An apparatus comprising: a transmitter configured to send, to a wireless communication device, a plurality of random access preambles in a plurality of beam directions, wherein each of the plurality of random access preambles is transmitted in a different beam direction, and wherein the plurality of random access preambles are associated with multiple random access opportunities of a random access attempt; and a receiver configured to receive, from the wireless communication device in response to at least a first random access preamble of the plurality of random access preambles, a first random access response (RAR) message in a first beam direction of the plurality of beam directions, wherein the first RAR message in the first beam direction is time-multiplexed with a second RAR message in a second beam direction of the plurality of beam directions within a subframe, wherein the second beam direction is different from the first beam direction, and wherein each of the first RAR message and the second RAR message includes at least one orthogonal frequency division multiplexing (OFDM) symbol within the subframe, wherein the receiver is further configured to receive the one or more RAR messages by: receiving, in the subframe, first control information and first data of the first RAR message in the first beam direction; and receiving, in the same subframe after receiving the first control information and the first data, second control information and second data of the second RAR message in the second beam direction, or wherein the receiver is further configured to receive the one or more RAR messages by: receiving, in the subframe, first control information of the first RAR message in the first beam direction; receiving, in the same subframe after receiving the first control information, second control information of the second RAR message in the second beam direction; receiving, in the same subframe after receiving the second control information, first data of the first RAR message in the first beam direction; and receiving, in the same subframe after receiving the first data, second data of the second RAR message in the second beam direction.

23. The apparatus of claim 22, wherein each RAR message spans at least a mini-slot including at least one OFDM symbol.

24. The apparatus of claim 22, wherein the receiver is further configured to receive the one or more RAR messages by: receiving, in the subframe, the first control information and the first data of the first RAR message in the first beam direction; and receiving, in the same subframe after receiving the first control information and the first data, second control information and second data of the second RAR message in the second beam direction.

25. The apparatus of claim 22, wherein the receiver is further configured to receive the one or more RAR messages by: receiving, in the subframe, the first control information of the first RAR message in the first beam direction; receiving, in the same subframe after receiving the first control information, the second control information of the second RAR message in the second beam direction; receiving, in the same subframe after receiving the second control information, the first data of the first RAR message in the first beam direction; and receiving, in the same subframe after receiving the first data, the second data of the second RAR message in the second beam direction.

26. The apparatus of claim 22, wherein the receiver is further configured to receive, from the wireless communication device, a rule for transmitting multiple random access preambles using multiple random access opportunities in different beam directions per random access attempt prior to RAR message monitoring, wherein the apparatus further comprises a processor configured to determine whether the UE satisfies the rule, and wherein the plurality of random access preambles are transmitted when the UE is determined to satisfy the rule.

27. The apparatus of claim 22, further comprising a processor configured to: monitor for the first RAR message in the first beam direction; and monitor for the second RAR message in the second beam direction.

28. The apparatus of claim 22, further comprising a processor configured to: determine whether the first beam direction has a higher reception quality than the second beam direction; and monitoring for the first RAR message in the first beam direction in a RAR window associated with the first RAR message when the first beam direction is determined to have the higher reception quality than the second beam direction.

29. The apparatus of claim 22, further comprising a processor configured to configure a beam in at least the first beam direction and the second beam direction to monitor for the first RAR message and the second RAR message.

30. The apparatus of claim 22, wherein the receiver is further configured to receive, from the wireless communication device, a transmission configuration indicating information associated with a random access message transmission time interval that is less than a system nominal subframe.