

Systems and Methods for OFDM with Flexible Sub-Carrier Spacing and Symbol Duration

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 61/949,805 filed on March 7, 2014 by Jianglei Ma et al. and entitled “OFDM System with Flexible Frequency-Time Lattice,” which is hereby incorporated herein by reference as if reproduced in its entirety, as well as to US Patent Application Serial Number 14/627,836 entitled “Systems and Methods for OFDM with Flexible Sub-Carrier Spacing and Symbol Duration” which is also incorporated herein by reference as if reproduced in its entirety.

TECHNICAL FIELD

[0002] The present invention relates to wireless communications, and, in particular embodiments, to systems and methods for transmitting different waveforms using flexible sub-carrier spacing and symbol duration. In some particular embodiments, the waveforms are orthogonal frequency division multiplexed (OFDM) waveforms having different parameters.

BACKGROUND

[0003] In existing wireless standards, including those for fourth generation (4G) and earlier wireless networks, a standardized waveform has been selected based on its suitability for general use. There are a variety of situations in which a different waveform may provide better performance, but to address overall performance and implementation limitations, only the standardized waveform is available. By using a single waveform, both transmitter and receiver designs can be simplified and added computations complexity can be avoided. However, to provide improved performance in an ever increasing number of deployment scenarios, the use of a single waveform is an obstacle that can impede performance. 4G networks make use of an orthogonal frequency division multiplexed (OFDM) waveform due to a number of characteristics. In many scenarios, it may be beneficial to allow for different OFDM waveform configurations for different channel conditions and/or different deployment/application scenarios. Consequently, next generation wireless communication protocols will likely include air interfaces that support waveform adaptation to allow the most suitable waveform to be dynamically selected based on various criteria, such as channel conditions, traffic types, transmission mode, user equipment (UE) capabilities, or other factors. As such, techniques and/or mechanisms for providing flexible air interfaces that are capable of being seamlessly adapted for diverse waveforms are desired, e.g., to offer resilient radio performance efficiently under various channel conditions.

SUMMARY OF THE INVENTION

[0004] In accordance with a first aspect of the present invention, a method by a network controller supporting wireless communications includes establishing a plurality of multiple access block (MAB) types defining different combinations of sub-carrier spacing and symbol duration for waveform transmissions. The method further includes partitioning a frequency and time plane of a carrier spectrum band into a plurality of MAB regions comprising frequency-time slots for the waveform transmissions. At least two different MAB types from the established plurality of MAB types are then selected for the MAB regions.

[0005] In accordance with a second aspect of the present invention, a method by a network component supporting wireless communications includes selecting a MAB region of a plurality of predetermined MAB regions partitioning a frequency and time plane of a carrier spectrum band, and transmitting a signal on frequency-time slots in the MAB region in accordance with a MAB type selected for the MAB region. The MAB type is from a plurality of predetermined MAB types. The method further includes reducing a bandwidth of the transmitted signal using a spectrum filter in accordance with a bandwidth of the MAB type.

[0006] In accordance with a third aspect of the present invention, a method by a network device supporting wireless communications includes receiving a signal on frequency-time slots in a MAB region of a plurality of MAB regions partitioning a frequency and time plane of a carrier spectrum band, and identifying a MAB type selected for the MAB region and defining a sub-carrier spacing and a symbol duration for the frequency-time slots of the MAB region. The method further includes establishing a spectrum filter with bandwidth in accordance with the MAB type, and detecting the signal using the spectrum filter.

[0007] In accordance with a fourth aspect of the present invention, a network controller supporting wireless communications comprises at least one processor and a non-transitory computer readable storage medium storing programming for execution by the at least one processor. The programming includes instructions to establish a plurality of MAB types defining different combinations of sub-carrier spacing and symbol duration for waveform transmissions, and partition a frequency and time plane of a carrier spectrum band into a plurality of MAB regions comprising frequency-time slots for the waveform transmissions. The network controller also selects, for the MAB regions, at least two different MAB types from the established MAB types.

[0008] In accordance with a fifth aspect of the present invention, a network component supporting wireless communications comprises at least one processor and a non-transitory computer readable storage medium storing programming for execution by the at least one processor. The programming includes instructions to select a MAB region of a plurality of predetermined MAB regions partitioning a frequency and time plane of a carrier spectrum band, and transmit a signal on frequency-time slots in the MAB region in accordance with a MAB type selected for the MAB region. The MAB type is from a plurality of predetermined MAB types. The network component is further configured to reduce a bandwidth of the transmitted signal using a spectrum filter in accordance with a bandwidth of the MAB type.

[0009] In accordance with a sixth aspect of the present invention, a network device supporting wireless communications comprises at least one processor and a non-transitory computer readable storage medium storing programming for execution by the at least one processor. The programming includes instructions to obtain a signal on frequency-time slots in a MAB region of a plurality of MAB regions partitioning a frequency and time plane of a carrier spectrum band, and identify a MAB type selected for the MAB region and defining a sub-carrier spacing and a symbol duration for the frequency-time slots of the MAB region. The network device is further configured to establish a spectrum filter with a bandwidth in accordance with the MAB type, and detect the signal using the spectrum filter.

[0010] The foregoing has outlined rather broadly the features of an embodiment of the present invention in order that the detailed description of the invention that follows may be better understood. Additional features and advantages of embodiments of the invention will be described hereinafter, which form the subject of the claims of the invention. It should be appreciated by those skilled in the art that the conception and specific embodiments disclosed may be readily utilized as a basis for modifying or designing other structures or processes for carrying out the same purposes of the present invention. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] For a more complete understanding of the present invention, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawing, in which:

[0012] FIG. 1 illustrates a diagram of an embodiment wireless communications network;

not to be limited to the details given herein. For example, the various elements or components may be combined or integrated in another system or certain features may be omitted, or not implemented.

[0044] In embodiments of the invention there is provided a method by a network component

5 supporting wireless communications, the method comprising:

selecting a multiple access block, MAB, region of a plurality of predetermined MAB regions partitioning a frequency and time plane of a carrier spectrum band;

transmitting a signal on frequency-time slots in the selected MAB region in accordance with a MAB type selected for the MAB region, wherein the MAB type is from a
10 plurality of predetermined MAB types; and

reducing a bandwidth of the transmitted signal using a spectrum filter selected in accordance with a bandwidth of the MAB type.

[0045] The method can further comprise:

selecting a second MAB region of the plurality of predetermined MAB regions;
15 transmitting a second signal on frequency-time slots in the second MAB region in accordance with a MAB type selected for the second MAB region, wherein the MAB type of the second MAB region is from the predetermined MAB types; and
reducing a bandwidth of the transmitted second signal using a second spectrum filter in accordance with a bandwidth of the second MAB type.

20 **[0046]** In another embodiment, the MAB type is a MAB type of frequency-time slots having a largest sub-carrier spacing and a longest cyclic prefix length among the MAB types, and wherein the method further comprises transmitting, on the frequency-time slots of the MAB type, information associated with at least one of a regional common channel, a

synchronization channel, a broadcast channel, a channel for ultra-high mobility devices, and a channel for coordinated multipoint, CoMP, transmissions.

[0047] In a further embodiment, the MAB type is a first MAB type of frequency-time slots having a smallest sub-carrier spacing and a longest cyclic prefix length among the MAB types, and wherein the method further comprises transmitting, on the frequency-time slots of the first MAB type, information associated with at least one of a channel for low mobility devices, a channel supporting large scale coordinated multipoint, CoMP, transmissions and a channel providing broadcasting service from more than one transmitters. Optionally, in this embodiment, the MAB types include a second MAB type of frequency-time slots having a larger sub-carrier spacing and a larger cyclic prefix length than the first MAB type, and wherein the method further comprises transmitting, on the frequency-time slots of the second MAB type, information associated with at least one of a channel for medium mobility devices and a channel supporting small scale coordinated multipoint, CoMP, transmissions. In a further embodiment, the MAB types include a third MAB type of frequency-time slots having a larger sub-carrier spacing and a smaller cyclic prefix length than the first MAB type and the second MAB type, and wherein the method further comprises comprising transmitting, on the frequency-time slots of the third MAB type, information associated with at least one of a channel for highest mobility devices, a channel supporting non-coordinated multipoint, CoMP, transmissions, and a channel requiring low latency.

[0048] In another embodiment of the invention, there is provided a method (800) by a network device supporting wireless communications, the method comprising:

receiving (810) a signal on frequency-time slots in a multiple access block, MAB, region of a plurality of MAB regions partitioning a frequency and time plane of a carrier spectrum band;

identifying, from a plurality of defined MAB types, a MAB type selected for the MAB region and defining a sub-carrier spacing and a symbol duration for the frequency-time slots of the MAB region;

establishing a spectrum filter with bandwidth in accordance with the MAB type;

5 and

detecting (820) the signal using the spectrum filter.

[0049] In an embodiment, the method further comprises:

receiving a second signal on second frequency-time slots in a second MAB region of the MAB regions;

10 identifying a second MAB type selected for the second MAB region and defining at least one of a second sub-carrier spacing and a second symbol duration for the second frequency-time slots;

establishing a second spectrum filter with a sub-carrier spacing in accordance with the second MAB type; and

15 detecting the second signal using the second spectrum filter.

[0050] In another embodiment, the method further comprises receiving a signaling of parameters indicating at least one of the MAB types and the MAB regions, wherein the parameters indicate a sub-carrier spacing, a useful symbol length, and a cyclic prefix length of the at least one of the MAB types.

20 **[0051]** In another embodiment, the method further comprises receiving a mapping of at least one of a MAB region of the MAB regions to at least one of a MAB type selected for the MAB region.

[0052] In a further embodiment, the MAB types include a special MAB type of frequency-time slots having a largest sub-carrier spacing and a longest cyclic prefix length among the MAB types, and wherein the method further comprises receiving, on the frequency-time slots of the special MAB type, information associated with at least one of a regional common
5 channel, a synchronization channel, a broadcast channel, a channel for ultra-high mobility devices, and a channel for coordinated multipoint, CoMP, transmissions.

[0053] In another embodiment of the invention there is , a network device supporting wireless communications, the network device comprising:

at least one processor;

10 a non-transitory computer readable storage medium storing programming for execution by the at least one processor, the programming including instructions to:

obtain a signal on frequency-time slots in a multiple access block, MAB,
region of a plurality of MAB regions partitioning a frequency and time plane of a
carrier spectrum band;

15 identify, from a plurality of defined MAB types, a MAB type selected for the MAB region and defining a sub-carrier spacing and a symbol duration for the frequency-time slots of the MAB region;

establish a spectrum filter with a bandwidth in accordance with the MAB type;

and

20 detect the signal using the spectrum filter.

[0054] In a further embodiment, the programming includes further instructions to obtain a signaling of parameters indicating at least one of the MAB types and the MAB regions, wherein the parameters indicate a sub-carrier spacing, a useful symbol length, and a cyclic prefix length of the at least one of the MAB types.

[0055] In another embodiment, the network device is a user equipment, UE, capable of communications with a wireless network.

[0056] In a further embodiment, the network device is a base station or a radio access point of a wireless network.

5 **[0057]** In another embodiment of the invention, there may be a network component supporting wireless communications, the network component comprising:

at least one processor; and

a non-transitory computer readable storage medium storing programming for execution by the at least one processor, the programming including instructions to:

10 select a multiple access block, MAB, region of a plurality of predetermined MAB regions partitioning a frequency and time plane of a carrier spectrum band;

transmit a signal on frequency-time slots in the MAB region in accordance with a MAB type selected for the MAB region, wherein the MAB type is from a plurality of predetermined MAB types; and

15 reduce a bandwidth of the transmitted signal using a spectrum filter in accordance with a bandwidth of the MAB type.

[0058] In an embodiment, the programming includes further instructions to:

select a second MAB region of the MAB regions;

20 transmit a second signal on second frequency-time slots in the second MAB region in accordance with a second MAB type selected for the second MAB region, wherein the second MAB type is from the predetermined MAB types; and

reduce a bandwidth of the transmitted second signal using a second spectrum filter in accordance with a bandwidth of the second MAB type.

[0059] In another embodiment, the network component is a base station or a radio access point of a wireless network.

[0060] In a further embodiment, the network component is a user equipment, UE, capable of communications with a wireless network.

5 **[0061]** In addition, techniques, systems, subsystems, and methods described and illustrated in the various embodiments as discrete or separate may be combined or integrated with other systems, modules, techniques, or methods without departing from the scope of the present disclosure. Other items shown or discussed as coupled or directly coupled or communicating with each other may be indirectly coupled or communicating through some interface, device,
10 or intermediate component whether electrically, mechanically, or otherwise. Other examples of changes, substitutions, and alterations are ascertainable by one skilled in the art and could be made without departing from the scope disclosed herein.

WHAT IS CLAIMED IS:

1. A method (700) performed by
a network controller supporting wireless communications, the
method comprising:

establishing a plurality of multiple access block, MAB, types (710) defining different
5 combinations of sub-carrier spacing and symbol duration for waveform transmissions;

partitioning a frequency and time plane of a carrier spectrum band into a plurality of
MAB regions (720) comprising frequency-time slots for the waveform transmissions; and
selecting, for the MAB regions, at least two different MAB types (730) from the established
plurality of MAB types; characterized in that

10 at least a first MAB region and a second MAB region of the plurality of MAB regions
occupy different frequency partitions of the carrier spectrum band in a same time slot; and a
first sub-carrier spacing in the first MAB region equals two times or four times a second sub-
carrier spacing in the second MAB region, wherein said first sub-carrier spacing is associated with
said first MAB region and said second sub-carrier spacing is associated with said second MAB region.

2. The method (700) of claim 1 further comprising arranging, at a transmitter of
15 the network controller, the frequency-time slots in the MAB regions in accordance with the
sub-carrier spacing and the symbol duration of the at least two different MAB types selected
for the MAB regions.

3. The method (700) of any one of claims 1 and 2, wherein the MAB types are selected
for the MAB regions according to at least one of a channel type, a transmission mode, a
20 propagation channel condition and a quality of service, QoS, requirement associated with the
MAB regions.

4. The method (700) of any one of claim 1 to 3 further comprising signaling (730), to
one or more network devices, parameters indicating a sub-carrier spacing, a useful symbol
length, and a cyclic prefix length of at least one of the MAB types.

25 5. The method (700) of any one of claims 1 to 4 further comprising signaling, to one or
more network devices, a mapping one of the MAB regions to at least one of a MAB type
selected for the MAB region, a corresponding type of traffic or transmission channel, and a
corresponding communications channel.

6. The method (700) of any one of claims 1 to 5, wherein the MAB types include a MAB type of frequency-time slots having a largest sub-carrier spacing and a longest cyclic prefix length among the MAB types.
7. The method(700) of any one of claims 1 to 6, wherein the MAB types include a first
5 MAB type of frequency-time slots having a smallest sub-carrier spacing and a longest cyclic prefix length among the MAB types.
8. The method (700) of claim 7, wherein the MAB types include a second MAB type of frequency-time slots having a larger sub-carrier spacing and a larger cyclic prefix length than the first MAB type.
9. The method (700) of claim 8, wherein the MAB types include a third MAB type of frequency-time slots having a larger sub-carrier spacing and a smaller cyclic prefix length than the first MAB type and the second MAB type.
10. The method(700) of any one of claims 1 to 9, wherein the waveform transmissions is one of Orthogonal Frequency Division, OFDM,
transmissions, Filtered OFDM, F-OFDM, transmissions, and Filter Bank
15 Multi-Carrier, FBMC, transmissions.
11. A network controller supporting wireless communications, the network controller comprising:
at least one processor; and
a non-transitory computer readable storage medium storing a computer program for
20 execution by the at least one processor, the computer program comprising instructions which, when executed by the processor, cause the processor to:
establish a plurality of multiple access block , MAB, types defining different combinations of sub-carrier spacing and symbol duration for waveform transmissions;
partition a frequency and time plane of a carrier spectrum band into a plurality of MAB regions comprising frequency-time slots for the waveform transmissions; and
25 select, for the MAB regions, at least two different MAB types from the established plurality of MAB types; the network controller being characterized in that
at least a first MAB region and a second MAB region of the plurality of MAB regions occupy different frequency partitions of the carrier spectrum band in a same time slot; and a

first sub-carrier spacing in the first MAB region equals two times or four times a second sub-carrier spacing in the second MAB region, wherein said first sub-carrier spacing is associated with said first MAB region and said second sub-carrier spacing is associated with said second MAB region.

12. The network controller of claim 11, wherein the computer program further includes instructions to cause the processor to arrange, at a

5 transmitter of the network controller, the frequency-time slots in the MAB regions in accordance with the sub-carrier spacing and the symbol duration of the at least two different MAB types selected for the MAB regions.

13. The network controller of any one of claims 11 and 12, wherein the computer program further includes instructions to cause the processor

10 to signal, to one or more network devices, parameters indicating a sub-carrier spacing, a useful symbol length, and a cyclic prefix length of at least one of the MAB types.