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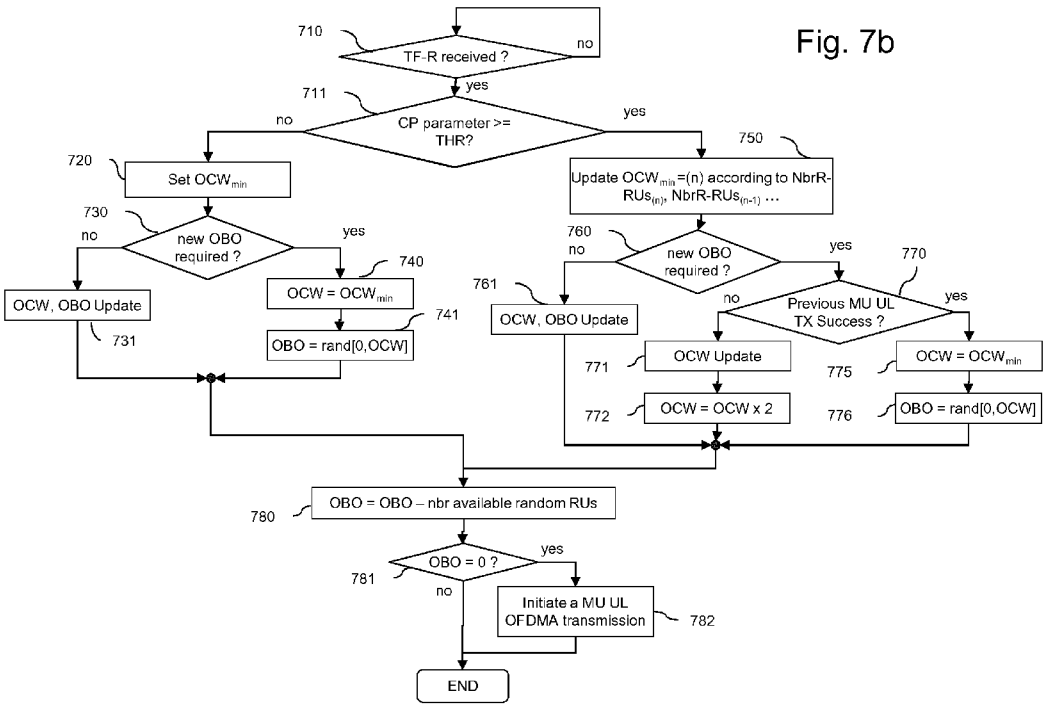
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Fig. 7b



(57) Abstract: The invention relates to the management of contention parameters of nodes contending for access to random resource units defined in trigger frames sent by an access point. The access point periodically sends a reference contention window for the nodes, for instance through beacon frames. Next, the access point controls how the nodes update their contention parameters using a CP parameter indicated in each sent trigger frame. Based on the CP parameter, the nodes select one or the other updating scheme based on which they update their contention parameters. The contention window may be kept unchanged if the CP parameter indicates a low loaded network, while it may be doubled if the CP parameter indicated a high loaded network. The OFDMA backoff value to contend for access to the random RUs may be continuously updated based on the number of random RUs made available to the nodes.

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UPDATING OF CONTENTION PARAMETERS FOR MU UL OFDMA TRANSMISSION IN AN 802.11AX NETWORK

FIELD OF THE INVENTION

The present invention relates generally to communication networks and more specifically to wireless communication methods in wireless network comprising an access point and a plurality of nodes, and corresponding devices.

The invention finds application in wireless communication networks, in particular to the access of an 802.11ax composite channel and of OFDMA Resource Units forming for instance an 802.11ax composite channel for Uplink communication to the access point. One application of the method regards wireless data communication over a wireless communication network using Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA), the network being accessible by a plurality of node devices.

BACKGROUND OF THE INVENTION

The IEEE 802.11 MAC standard defines a way wireless local area networks (WLANs) must work at the physical and medium access control (MAC) level. Typically, the 802.11 MAC (Medium Access Control) operating mode implements the well-known Distributed Coordination Function (DCF) which relies on a contention-based mechanism based on the so-called “Carrier Sense Multiple Access with Collision Avoidance” (CSMA/CA) technique.

The 802.11 medium access protocol standard or operating mode is mainly directed to the management of communication nodes waiting for the wireless medium to become idle so as to try to access to the wireless medium.

The network operating mode defined by the IEEE 802.11ac standard provides very high throughput (VHT) by, among other means, moving from the 2.4GHz band which is deemed to be highly susceptible to interference to the 5GHz band, thereby allowing for wider frequency contiguous channels of 80 MHz to be used, two of which may optionally be combined to get a 160 MHz composite channel as operating band of the wireless network.

The 802.11ac standard also tweaks control frames such as the Request-To-Send (RTS) and Clear-To-Send (CTS) frames to allow for composite channels of varying and predefined bandwidths of 20, 40 or 80 MHz, the composite channels being made of one or more channels that are contiguous within the operating band. The 160 MHz composite channel is possible by the combination of two 80 MHz composite channels within the 160 MHz operating band. The control frames specify the channel width (bandwidth) for the targeted (or “requested”) composite channel.

A composite channel therefore consists of a primary channel on which a given node performs EDCA backoff procedure to access the medium, and of at least one secondary channel, of for example 20 MHz each. The primary channel is used by the communication

nodes to sense whether or not the channel is idle, and the primary channel can be extended using the secondary channel or channels to form a composite channel.

Given a tree breakdown of the operating band into elementary 20 MHz channels, some secondary channels are named tertiary or quaternary channels.

In 802.11ac, all the transmissions, and thus the possible composite channels, include the primary channel. This is because the nodes perform full Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA) and Network Allocation Vector (NAV) tracking on the primary channel only. The other channels are assigned as secondary channels, on which the 802.11ac nodes have only capability of CCA (clear channel assessment), i.e. detection of an idle or busy state/status of said secondary channel.

An issue with the use of composite channels as defined in the 802.11n or 802.11ac is that the 802.11n and 802.11ac-compliant nodes (i.e. HT nodes standing for High Throughput nodes) and the other legacy nodes (i.e. non-HT nodes compliant only with for instance 802.11a/b/g) have to co-exist within the same wireless network and thus have to share the 20 MHz channels.

To cope with this issue, the 802.11n and 802.11ac standards provide the possibility to duplicate control frames (e.g. RTS/CTS or CTS-to-Self or ACK frames to acknowledge correct or erroneous reception of the sent data) on each 20MHz channel in an 802.11a legacy format (called as “non-HT”) to establish a protection of the requested channels forming the whole composite channel, during the TXOP.

This is for any legacy 802.11a node that uses any of the 20 MHz channel involved in the composite channel to be aware of on-going communications on the 20 MHz channel used. As a result, the legacy node is prevented from initiating a new transmission until the end (as set on the NAV parameter) of the current composite channel TXOP granted to an 802.11n/ac node.

As originally proposed by 802.11n, a duplication of conventional 802.11a or “non-HT” transmission is provided to allow the two identical 20 MHz non-HT control frames to be sent simultaneously on both the primary channel and the secondary channels forming the requested and used composite channel.

This approach has been widened for 802.11ac to allow duplication over the channels forming an 80 MHz or 160 MHz composite channel. In the remainder of the present document, the “duplicated non-HT frame” or “duplicated non-HT control frame” or “duplicated control frame” means that the node device duplicates the conventional or “non-HT” transmission of a given control frame over secondary 20 MHz channels of the (40/80/160 MHz) operating band.

In practice, to request a composite channel (equal to or greater than 40 MHz) for a new TXOP, an 802.11n/ac node does an EDCA backoff procedure in the primary 20 MHz channel wherein one or more backoff counters are decremented. In parallel, it performs a channel sensing mechanism, such as a Clear-Channel-Assessment (CCA) signal detection, on

the secondary channels to detect the secondary channel or channels that are idle (channel state/status is "idle") during a PIFS interval before sending a request for the new TXOP (i.e. before the backoff counter expires).

More recently, Institute of Electrical and Electronics Engineers (IEEE) officially approved the 802.11ax task group, as the successor of 802.11ac. The primary goal of the 802.11ax task group consists in seeking for an improvement in data speed to wireless communicating devices used in dense deployment scenarios.

Recent developments in the 802.11ax standard sought to optimize usage of the composite channel by multiple nodes in a wireless network having an access point (AP). Indeed, typical contents have important amount of data, for instance related to high-definition audio-visual real-time and interactive content. Furthermore, it is well-known that the performance of the CSMA/CA protocol used in the IEEE 802.11 standard deteriorates rapidly as the number of nodes and the amount of traffic increase, i.e. in dense WLAN scenarios.

In this context, multi-user transmission has been considered to allow multiple simultaneous transmissions to/from different users in both downlink and uplink directions from/to the AP. In the uplink to the AP, multi-user transmissions can be used to mitigate the collision probability by allowing multiple nodes to simultaneously transmit.

To actually perform such multi-user transmission, it has been proposed to split a granted 20MHz channel into sub-channels, also referred to as resource units (RUs), that are shared in the frequency domain by the multiple nodes, based for instance on Orthogonal Frequency Division Multiple Access (OFDMA) technique. Each RU may be defined by a number of tones, the 20MHz channel containing up to 242 usable tones.

OFDMA is a multi-user variation of OFDM which has emerged as a new key technology to improve efficiency in advanced infrastructure-based wireless networks. It combines OFDM on the physical layer with Frequency Division Multiple Access (FDMA) on the MAC layer, allowing different subcarriers to be assigned to different nodes in order to increase concurrency. Adjacent sub-carriers often experience similar channel conditions and are thus grouped to sub-channels: an OFDMA sub-channel or RU is thus a set of sub-carriers.

The multi-user feature of OFDMA allows the AP to assign different RUs to different nodes in order to increase competition. This may help to reduce contention and collisions inside 802.11 networks.

As currently envisaged, the granularity of such OFDMA sub-channels is finer than the original 20MHz channel band. Typically, a 2MHz or 5MHz sub-channel may be contemplated as a minimal width, therefore defining for instance 9 sub-channels or resource units within a single 20MHz channel.

To support multi-user uplink, i.e. uplink transmission to the 802.11ax access point (AP) during the granted TxOP, the 802.11ax AP has to provide signalling information for the legacy nodes (non-802.11ax nodes) to set their NAV and for the 802.11ax nodes to determine the allocation of the resource units RUs.

It has been proposed for the AP to send a trigger frame (TF) to the 802.11ax nodes to trigger uplink communications.

The document IEEE 802.11-15/0365 proposes that a 'Trigger' frame (TF) is sent by the AP to solicit the transmission of uplink (UL) Multi-User (OFDMA) PPDU from multiple nodes. In response, 802.11ax nodes transmit UL MU (OFDMA) PPDU as immediate responses to the Trigger frame. All 802.11ax transmitters can send data at the same time, but using disjoint RUs or sets of RUs (i.e. of frequencies in the OFDMA scheme), resulting in transmissions with less interference.

The bandwidth or width of the targeted composite channel is signalled in the TF frame, meaning that the 20, 40, 80 or 160 MHz value is added. The TF frame is sent over the primary 20MHz channel and duplicated (replicated) on each other 20MHz channels forming the targeted composite channel, if appropriate. As described above for the duplication of control frames, it is expected that every nearby legacy node (non-HT or 802.11ac nodes) receiving the TF on its primary channel, then sets its NAV to the value specified in the TF frame. This prevents these legacy nodes from accessing the channels of the targeted composite channel during the TXOP.

A resource unit RU can be reserved for a specific node, in which case the AP indicates, in the TF, the node to which the RU is reserved. Such RU is called Scheduled RU. The indicated node does not need to perform contention on accessing a scheduled RU reserved to it.

In order to better improve the efficiency of the system in regards to un-managed traffic to the AP (for example, uplink management frames from associated nodes, unassociated nodes intending to reach an AP, or simply unmanaged data traffic), the document IEEE 802.11-15/0604 proposes a new trigger frame (TF-R) above the previous UL MU procedure, allowing random access onto the OFDMA TXOP. In other words, each resource unit RU defined by the new TF-R can be randomly accessed by more than one node (of the group of nodes registered with the AP). Such RU is called Random RU and is indicated as such in the TF. Random RUs may serve as a basis for contention between nodes willing to access the communication medium for sending data.

A random resource selection procedure is defined in document IEEE 802.11-15/1105. According to this procedure, each 802.11ax node maintains a dedicated backoff engine, referred below to as OFDMA or RU (for resource unit) backoff engine, to contend for access to the random RUs defined by the TF-R. The dedicated OFDMA or RU backoff, also called OBO, is randomly assigned in a contention window range [0, OCW] wherein OCW is the OFDMA contention window defined in a selection range [OCW_{min}, OCW_{max}].

Once the current OBO backoff value reaches zero in a node (it is decremented at each new TF-R frame by the number of random RUs defined therein for instance), the node becomes eligible for RU access and thus can randomly select one RU from among all the

random RUs defined in the received trigger frame. It then uses the selected RU to transmit data of at least one of the traffic queues.

The standard does not specify how the OFDMA or RU backoff engine must be managed, in particular to efficiently react to changing network conditions, for instance as the number of nodes in the wireless network, and/or as the number of random resource units, and/or as the amount of data traffic substantially vary.

There is thus a need to provide an efficient management of the OFDMA or RU backoff engine at the nodes.

SUMMARY OF INVENTION

Figure 9 shows the evolution of network efficiency due to random RUs (thin solid line) as a function of the number of nodes involves in the wireless network, given a fixed number of random RUs available to the nodes for contention and a fixed OCW. The Figure also depicts the evolution of unused random RUs (dashed line) and of collided random RUs (dotted line). The collided random RUs are those random RUs accessed simultaneously by two nodes contending for an RU access.

The network efficiency as shown in the Figure may be a ratio between the number of non-collided and actually used random RUs, and the number of random RUs available to the nodes.

From this Figure, one may understand that the OFDMA contention window OCW should be increased as the number of nodes increases (if the number of random RUs is fixed) or as the number of random RUs decreases (if the number of nodes is fixed). This is because in these situations competition between the nodes to access the random RUs is high. Thus increasing OCW would spread the random RU accesses by the nodes over a wider time period.

The OFDMA contention window OCW is thus strongly linked to the number of nodes willing to get (i.e. contending) a resource unit (RU) for the next multi user (MU) uplink (UL) OFDMA transmission and also to the number of resource units (RU) defined by the current trigger frame. More generally, the contention parameters that evolve at each node are strongly linked to these numbers.

However, the nodes cannot estimate accurately the number of nodes competing for an access to the random RUs. That is why known techniques used to manage the EDCA backoff procedure and that could be implemented to the OFDMA backoff procedure are implemented to adjust the OCW value or other contention parameters at the nodes, depending on parameters the nodes can evaluate. This is because controlling backoff parameters makes it possible to drive the OBO backoff value used to contend for RU access, and thus allows performance of the multi user (MU) uplink (UL) OFDMA transmissions to be optimized.

Most often the OBO backoff value is driven through its associated OFDMA window contention OCW, which may for instance be updated upon success or failure of each UL OFDMA transmission by the node concerned. For instance, the OCW is doubled in case of

failure, while it is reset to a low value in case of success. The thick solid line in **Figure 9** shows an average behavior of the network efficiency as the number of nodes increases, when the doubling of OCW in case of transmission failure is implemented.

However, the doubling of OCW, and more generally the updating schemes envisioned to update the contention parameters at the nodes, are not fully satisfactory. For instance, the inventors have noticed that the doubling of OCW is badly adapted to networks lowly used, i.e. with unused random resource units. Indeed, in this case, only accidental collisions over random RUs occur since random resource units are still available. However, these accidental collisions have an heavy impact on contention, due to the doubling of OCW, as they have to wait more on average before accessing the random resource units, despite they are some still available.

The present invention thus seeks to improve this situation, with a view of increasing or optimizing network efficiency.

In this context, embodiments of the invention provide a wireless communication method in a wireless network comprising an access point and a plurality of nodes as defined in the claims.

Embodiments may also provide a method that comprises, at one of said nodes:

receiving trigger frames over time from the access point, each trigger frame reserving a transmission opportunity on at least one communication channel of the wireless network and defining resource units forming the communication channel during the transmission opportunity, including one or more random resource units the nodes access using a contention scheme;

retrieving a contention policy parameter from a received current trigger frame;

selecting, based on a value of the retrieved contention policy parameter, an updating scheme from amongst a plurality of different updating schemes to update at least one contention parameter driving the contention scheme at said node;

applying the selected updating scheme to update the contention parameter or parameters; and

contending for access to a random resource unit using the contention scheme based on the updated contention parameter or parameters.

From the access point's perspective, a wireless communication method is proposed in a wireless network comprising an access point and a plurality of nodes, as defined in the claims.

Embodiments may also provide a method that comprises, at the access point:

sending trigger frames over time, each trigger frame reserving a transmission opportunity on at least one communication channel of the wireless network and defining resource units forming the communication channel during the transmission opportunity, including one or more random resource units the nodes access using a contention scheme;

receiving data from the nodes over some of the random resource units;

determining a contention policy parameter;

wherein a sent trigger frame includes the determined contention policy parameter to drive the nodes in selecting an updating scheme from a plurality of different updating schemes to update at least one local contention parameter.

The present invention improves use of the random resource units, and thus network efficiency.

This is achieved by the inventive combination of two tricks.

On one hand, the access point provides the nodes with an overview of the network conditions, thanks to the transmitted contention policy parameter. In particular this parameter may reflect information the nodes cannot know by their own, e.g. number of nodes competing to access the random RUs, statistics on the use of the random RUs, etc.

On the other hand, based on such indication from the access point, the nodes are able to adjust the updating of their contention scheme in order to reflect the current situation of the network. In particular, the indication provided by the access point makes it possible for the nodes to distinguish between transmission failures occurring in light loading network conditions (in which case for instance the contention window can be kept unchanged or set to a low value) and transmission failures occurring in high loading network conditions (in which case for instance doubling of the contention window seems adapted).

As a consequence, the access point may efficiently drive the nodes on how to adapt their contention schemes.

Correspondingly, the same embodiments of the invention provide a communication device and/or an access point in a wireless network comprising an access point and a plurality of nodes, the device or the access point comprising at least one microprocessor configured for carrying out the steps defined above.

Optional features of embodiments of the invention are defined in the appended claims. Some of these features are explained here below with reference to a method, while they can be transposed into system features dedicated to any node device according to embodiments of the invention.

In embodiments, the contention scheme at said node decrements a current backoff value of a backoff counter initially selected from a contention window and triggers access to a random resource unit upon the current backoff value reaching a target value, usually 0.

In that case, the at least one contention parameter may include the contention window, and the method further comprises generating a new backoff value by selection from the updated contention window. Controlling the contention window through the mechanisms of the invention thus makes it possible to efficiently drive the backoff value generation, and thus the access to the random resource units by the nodes.

In specific embodiments, the selecting step is triggered when a new backoff value has to be generated in order to contend for access to a random resource unit defined by the

received current trigger frame, using a new backoff value selected from the updated contention window.

In some embodiments, the at least one contention parameter to be updated includes the contention window, and a first one of the updating schemes sets the contention window to a by-default value.

For instance, the contention window is selected from a selection range ([OCW_{min}, OCW_{max}]), and the by-default value is a lowest boundary of the selection range, i.e. OCW_{min} as mentioned above.

In some embodiments, a second one of the updating schemes updates the contention window depending on success or failure of a last transmission of data by said node to the access point over an accessed random resource unit.

This clearly shows that two available updating schemes modify the contention window in different fashion. This is particularly efficient when they are applied to a network situation where transmission failures are accidental and an overloaded network situation (where collisions are normal) respectively.

Indeed, in case of accidental failures within a light loaded network situation, the current contention scheme could be kept, while in case of normal failures due to overloading, the node should access the random RUs more rarely (by increasing the contention window for instance).

In specific embodiments, the second updating scheme multiplies the contention window by a multiplying factor in case of transmission failure, for instance by doubling it.

In more specific embodiments, the multiplying factor is twice a ratio between the number of random resource units defined by the received trigger frame immediately preceding the current trigger frame and the number of random resource units defined by the received current trigger frame. This makes it possible to take into account the changing number of random RUs made available to the nodes, while adjusting the contention window due to the failure of the last transmission. The resulting updated contention window is thus more adapted to the current network conditions for contention.

In specific embodiments, the contention window is selected from a selection range, and the second updating scheme sets the contention window to a lowest boundary of the selection range in case of transmission success. In a variant, the contention window may be kept unchanged. Indeed, as the transmission is a success there is no need to degrade the contention window (in the meaning the node accesses the random resource units more rarely on overall). In addition, the node may be rewarded by reducing its contention window to give it more chances to send more data over time.

In some embodiments, the retrieved contention policy parameter is representative of a collision rate computed by the access point over past random resource units defined by trigger frames preceding the received current trigger frame, and the first updating scheme is selected when the retrieved contention policy parameter indicates a low collision rate while the

second updating scheme is selected when the retrieved contention policy parameter indicates a high collision rate.

In other embodiments, the retrieved contention policy parameter is made of a single bit. The single bit can directly reflect either high or low collision rate. The signaling cost is thus made minimal.

In variants, the retrieved contention policy parameter includes a profile identifier identifying a collision profile from amongst a plurality of collision profiles shared between the access point and the nodes. This makes it possible to apply a various range of updating operations depending on the collision profiles.

In other variants, the retrieved contention policy parameter indicates a ratio between a number of random resource units over which collisions have been detected during a monitoring window and a number of random resource units made available to the nodes for contention during the monitoring window. Even if the nodes may apply the same rules on the retrieved ratio, this configuration makes it possible to slightly adapt the rules locally, for instance if hidden nodes are detected.

In some embodiments, the contention window is selected from a selection range, and the at least one contention parameter to be updated includes a lowest boundary of the selection range. These embodiments thus drive the backoff value for contention, from the management of OCW_{min}.

Of course, other contention parameters, such as OCW_{max}, may be updated based on the retrieved parameter.

In specific embodiments, a first one of the updating schemes updates the lowest boundary based on the number of random resource units defined by the received current trigger frame.

According to a specific feature, the lowest boundary is multiplied by a ratio between the number of random resource units defined by the received trigger frame immediately preceding the current trigger frame and the number of random resource units defined by the received current trigger frame. This is to adapt the current OCW_{min} to the evolution of the number of random resource units over the various trigger frames. The contention scheme at the nodes is thus continuously and dynamically adapted.

According to another specific feature, the multiplication-based update is made in case the retrieved contention policy parameter indicates a high collision rate in past random resource units defined by trigger frames preceding the received current trigger frame.

In other specific embodiments, another one of the updating schemes sets the lowest boundary to the number of random resource units defined by the received current trigger frame in case the retrieved contention policy parameter indicates a low collision rate in past random resource units defined by trigger frames preceding the received current trigger frame. Of course, other values for the updating may be used, such as a by-default OCW_{min} received from the access point, for instance in a last received beacon frame as explained below.

In some embodiments, the updating schemes update a non-zero current backoff value and the contention window, based on the number of random resource units defined by the received current trigger frame. In specific embodiments, each of the contention window and the non-zero current backoff value is multiplied by a ratio between the number of random resource units defined by the received trigger frame immediately preceding the current trigger frame and the number of random resource units defined by the received current trigger frame. This is also to continuously and dynamically adapt the current contention values of the contention scheme as the network conditions evolves (here evolution of the number of random resource units made available to the nodes).

In other embodiments, the current backoff value is decremented upon receiving each of the trigger frames, by the number of random resource units defined by the received trigger frame. This defines with more details the contention scheme implemented by the nodes.

In other embodiments, each received trigger frame includes a contention policy parameter. The access point thus drives continuously the nodes on how adapting their contention scheme/parameters.

In some embodiments, the node contends, based on the updated contention parameter or parameters, for access to a random resource unit defined by a received trigger frame following the received current trigger frame. It means that the nodes do not necessarily update their contention parameter because they want to access the random resource units of the current trigger frame. This makes it possible for the nodes to continuously adapt their own contention parameters over time so that the latter are best adapted when the node finally desires to access the random resource units.

In specific embodiments, the method further comprises, at said node:

retrieving a second contention policy parameter from the following trigger frame;

selecting, based on a value of the retrieved second contention policy parameter, a second updating scheme from amongst the plurality of different updating schemes; and

applying the selected second updating scheme to update again the updated contention parameter or parameters, before contending for access to the random resource unit based on the twice updated contention parameter or parameters.

This provision illustrates the continuous updating of the contention parameters as several trigger frames are received over time.

In some embodiments, the method further comprises, at said node, periodically receiving a beacon frame from the access point, each beacon frame broadcasting network information about the wireless network to the plurality of nodes,

wherein a received current beacon frame includes a by-default contention parameter for the contention scheme of said node.

This provision makes it possible for the access point to control the contention scheme of all the nodes. This is because providing them with by-default values ensures all the

nodes to periodically (a beacon frame can be sent every 100 ms) resynchronize on the network conditions as analyzed by the nodes and mirrored by the transmitted by-default values.

In specific embodiments, the contention window is selected from a selection range, and the by-default contention parameter included in the received current beacon frame includes a reference lower boundary for the selection range. The access point can thus periodically sets OCW_{min} to the nodes. Of course other contention parameters can be reset periodically.

According to a specific feature, the method further comprises, at said node upon receiving the current beacon frame, setting the lower boundary of the selection range to the reference lower boundary included in the received current beacon frame.

According to another specific feature, the method further comprises, at said node upon receiving the current beacon frame, setting the contention window to the reference lower boundary included in the received current beacon frame, i.e. to the lower boundary of the selection range of the node.

In specific embodiments, each received beacon frame includes a reference lower boundary. This is for the access point to continuously resynchronize the node's contention scheme to the actual network conditions as analyzed by the access point.

Regarding the access point, some optional embodiments may provide that the contention policy parameter is representative of a collision rate in the random resource units contended by the nodes. Of course the contention policy parameter may be representative of any other information that the nodes cannot determine by their own and that may impact the contention scheme, for instance the number of nodes competing for access to the random resource units.

In some embodiments, the method further comprises, at the access point, computing the collision rate as a ratio between a number of random resource units over which collisions are detected during a monitoring window and a number of random resource units made available to the nodes for contention during the monitoring window.

In specific embodiments, the method further comprises, at the access point, gathering statistics on use, by the nodes, of the random resource units defined in sent trigger frames, wherein the collision rate is computed based on the gathered statistics. Note that the statistics may be collected during a monitoring window and then analyzed, for instance during couples (e.g. 3 to 5) of trigger frames.

In some embodiments, the contention policy parameter is determined based on the computed collision rate.

According to a specific feature, the contention policy parameter is made of a single bit which takes a first value if the computed collision rate is below a predefined threshold and takes a second value if the computed collision rate is above the predefined threshold.

In variants, the method further comprises determining, from amongst a plurality of collision profiles shared between the access point and the nodes, a collision profile that

matches with a collision rate computed over time; wherein the contention policy parameter includes a profile identifier identifying the determined collision profile.

In other variants, the contention policy parameter includes the computed collision rate.

In some embodiments related to the beacon frames as briefly introduced above, the method further comprises, at the access point, periodically sending a beacon frame, each beacon frame broadcasting network information about the wireless network to the plurality of nodes, wherein a sent beacon frame includes a by-default contention parameter for the contention schemes of the nodes.

In specific embodiments, the contention schemes at the nodes are based on respective contention windows, and the by-default contention parameter included in the sent beacon frame includes a reference lower boundary to be used by nodes as a lower boundary of a selection range from which they select their respective contention window.

In specific embodiments, the method further comprises, at the access point, updating, based on a computed rate of collision in the random resource units contended by the nodes, a local reference lower boundary to be included in a next beacon frame. This is for the access point to dynamically adapt a local OCW_{min} mirroring the changing network conditions. Of course other contention parameters can be set locally before being sent to the nodes, e.g. OCW_{max}.

According to a specific feature, the collision rate is computed upon preparing a new beacon frame to be sent.

According to another specific feature, the local reference lower boundary is doubled if the computed collision rate is above an upper threshold. Indeed, such a collision rate indicates that too many nodes are accessing the random resource units at the same time. Thus increasing OCW_{min} will drive the nodes in accessing the random resource units less often.

According to yet another specific feature, the local reference lower boundary is reset to a by-default value if the computed collision rate is below a lower threshold. Indeed, in such a situation, it is often preferable to have a low OCW_{min} in order to have a better use of all the random resource units (since the collision rate is low, the unused random resource units may be numerous – see **Figure 9** for instance described above).

According to yet another specific feature, the upper threshold and the lower threshold are one and the same threshold. The access point thus distinguishes only between two network conditions.

According to yet another specific feature, the local reference lower boundary is kept unchanged if the computed collision rate is between the lower and upper thresholds. In this network situation, the access point considers the current situation as being optimal or satisfactory. Thus the current OCW_{min} can be kept unchanged.

According to yet another specific feature, the by-default value is a mean number of random resource units in trigger frames sent, e.g. over a monitoring window (e.g. 1 or 2 or more

up to 5 trigger frames). Thus, the access point encourages all the nodes in having access to a random resource unit at each trigger frame.

In embodiments, the communication channel is a 20 MHz channel according to the 802.11ax standard.

Another aspect of the invention relates to a wireless communication system having an access point and at least one communication device forming node as defined above.

Another aspect of the invention relates to a non-transitory computer-readable medium storing a program which, when executed by a microprocessor or computer system in a device, causes the device to perform any method as defined above.

The non-transitory computer-readable medium may have features and advantages that are analogous to those set out above and below in relation to the methods and node devices.

Another aspect of the invention relates to a communication method in a wireless network comprising an access point and a plurality of nodes, substantially as herein described with reference to, and as shown in, **Figure 6b**, or **Figure 7b**, or **Figures 6a** and **6b**, or **Figures 7a** and **7b**, or **Figures 6a**, **6b**, **7a** and **7b** of the accompanying drawings.

At least parts of the methods according to the invention may be computer implemented. Accordingly, the present invention may take the form of an entirely hardware embodiment, an entirely software embodiment (including firmware, resident software, micro-code, etc.) or an embodiment combining software and hardware aspects that may all generally be referred to herein as a "circuit", "module" or "system". Furthermore, the present invention may take the form of a computer program product embodied in any tangible medium of expression having computer usable program code embodied in the medium.

Since the present invention can be implemented in software, the present invention can be embodied as computer readable code for provision to a programmable apparatus on any suitable carrier medium. A tangible carrier medium may comprise a storage medium such as a hard disk drive, a magnetic tape device or a solid state memory device and the like. A transient carrier medium may include a signal such as an electrical signal, an electronic signal, an optical signal, an acoustic signal, a magnetic signal or an electromagnetic signal, e.g. a microwave or RF signal.

BRIEF DESCRIPTION OF THE DRAWINGS

Further advantages of the present invention will become apparent to those skilled in the art upon examination of the drawings and detailed description. Embodiments of the invention will now be described, by way of example only, and with reference to the following drawings.

Figure 1 illustrates a typical wireless communication system in which embodiments of the invention may be implemented;

Figure 2 illustrates 802.11ac channel allocation that supports composite channel bandwidths of 20 MHz, 40 MHz, 80 MHz or 160 MHz, as known in the art;

Figure 3 illustrates an example of 802.11ax uplink OFDMA transmission scheme, wherein the AP issues a Trigger Frame for reserving a transmission opportunity of OFDMA sub-channels (resource units) on an 80 MHz channel as known in the art;

Figure 4 shows a schematic representation a communication device or station in accordance with embodiments of the present invention;

Figure 5 shows a block diagram schematically illustrating the architecture of a wireless communication device in accordance with embodiments of the present invention;

Figure 6a illustrates, using a flowchart, general steps for an access point to build and send a beacon frame including a new OCW_{min} value, according to embodiments of the invention;

Figure 6b illustrates, using a flowchart, general steps for the access point to build and send a trigger frame including a contention policy parameter, according to embodiments of the invention;

Figure 7a illustrates, using a flowchart, general steps for any node to determine the OCW_{min} value received from the access point through a beacon frame, and to use it, according to embodiments of the invention;

Figure 7b illustrates, using a flowchart, general steps for any node to update contention parameters, including the contention window, upon reception of a trigger frame from the access point, according to embodiments of the invention;

Figure 8 illustrates the structure of a trigger frame;

Figure 9 illustrates network efficiency of a wireless network providing nodes with random resource units for contention, as a function of the number of nodes in the network; and

Figure 10 illustrates the benefits of the present invention in terms of network efficiency.

DETAILED DESCRIPTION

The invention will now be described by means of specific non-limiting exemplary embodiments and by reference to the figures.

Figure 1 illustrates a communication system in which several communication nodes (or stations) 101–107 exchange data frames over a radio transmission channel 100 of a wireless local area network (WLAN), under the management of a central station or “access point” (AP) 110. The radio transmission channel 100 is defined by an operating frequency band constituted by a single channel or a plurality of channels forming a composite channel.

Access to the shared radio medium to send data frames is based on the CSMA/CA technique, for sensing the carrier and avoiding collision by separating concurrent transmissions in space and time.

To meet the ever-increasing demand for faster wireless networks to support bandwidth-intensive applications, 802.11ac is targeting larger bandwidth transmission through multi-channel operations. **Figure 2** illustrates 802.11ac channel allocation that supports composite channel bandwidth of 20 MHz, 40 MHz, 80 MHz or 160 MHz.

IEEE 802.11ac introduces support of a restricted number of predefined subsets of 20 MHz channels to form the sole predefined composite channel configurations that are available for reservation by any 802.11ac node on the wireless network to transmit data.

The predefined subsets are shown in the Figure and correspond to 20 MHz, 40 MHz, 80 MHz, and 160 MHz composite channel bandwidths, compared to only 20 MHz and 40 MHz supported by 802.11n. Indeed, the 20 MHz component channels 400-1 to 400-8 are concatenated to form wider communication composite channels.

In the 802.11ac standard, the channels of each predefined 40 MHz, 80 MHz or 160 MHz subset are contiguous within the operating frequency band, i.e. no hole (missing channel) in the composite channel as ordered in the operating frequency band is allowed.

The 160 MHz channel bandwidth is composed of two 80 MHz channels that may or may not be frequency contiguous. The 80 MHz and 40 MHz channels are respectively composed of two frequency adjacent or contiguous 40 MHz and 20 MHz channels, respectively. The present invention may have embodiments with either composition of the channel bandwidth, i.e. including only contiguous channels or formed of non-contiguous channels within the operating band.

A node is granted a TXOP through the enhanced distributed channel access (EDCA) mechanism on the “primary channel” (300-3). Indeed, for each composite channel having a bandwidth, 802.11ac designates one 20 MHz channel as “primary”, meaning that it is used for contending for access to the composite channel. The primary 20 MHz channel is common to all nodes (STAs) belonging to the same basic set, i.e. managed by or registered to the same local Access Point (AP).

However, to make sure that no other legacy node (i.e. not belonging to the same set) uses the secondary channels, it is provided that the control frames (e.g. RTS frame/CTS frame) reserving the composite channel are duplicated over each 20MHz channel of such composite channel.

As addressed earlier, the IEEE 802.11ac standard enables up to four, or even eight, 20 MHz channels to be bound. Because of the limited number of channels (19 in the 5 GHz band in Europe), channel saturation becomes problematic. Indeed, in densely populated areas, the 5 GHz band will surely tend to saturate even with a 20 or 40 MHz bandwidth usage per Wireless-LAN cell.

Developments in the 802.11ax standard seek to enhance efficiency and usage of the wireless channel for dense environments.

In this perspective, one may consider multi-user (MU) transmission features, allowing multiple simultaneous transmissions to different users in both downlink and uplink

directions. In the uplink (UL), multi-user transmissions can be used to mitigate the collision probability by allowing multiple nodes to simultaneously transmit.

To actually perform such multi-user transmission, it has been proposed to split a granted 20 MHz channel (300-1 to 300-4) into sub-channels 310 (elementary sub-channels), also referred to as sub-carriers or resource units (RUs), that are shared in the frequency domain by multiple users, based for instance on Orthogonal Frequency Division Multiple Access (OFDMA) technique.

This is illustrated with reference to **Figure 3** which illustrates an example of uplink OFDMA transmission scheme. In this example, each 20 MHz channel (300-1, 300-2, 300-3 or 300-4) is sub-divided in frequency domain into four OFDMA sub-channels or RUs 310 of size 5 MHz. These sub-channels (or resource units or sets of "sub-carriers") may also be referred to as "traffic channels".

Of course the number of RUs splitting a 20 MHz channel may be different from four. For instance, between two to nine RUs may be provided (thus each having a size between 10 MHz and about 2 MHz).

Contrary to downlink OFDMA wherein the AP can directly send multiple data to multiple stations (supported by specific indications inside the PLCP header), a trigger mechanism has been adopted for the AP to trigger uplink communications from various nodes.

To support an uplink multi-user transmission (during a TXOP granted to the AP), the 802.11ax AP has to provide signalling information for both legacy nodes (non-802.11ax nodes) to set their NAV and 802.11ax nodes to determine the allocation of the resource units RUs.

In the following description, the term legacy refers to non-802.11ax nodes, meaning 802.11 nodes of previous technologies that do not support OFDMA communications.

As shown in the example of **Figure 5**, the AP sends a trigger frame (TF) 330 to the targeted 802.11ax nodes. The bandwidth or width of the targeted composite channel is signalled in the TF frame, meaning that the 20, 40, 80 or 160 MHz value is added. The TF frame is sent over the primary 20MHz channel and duplicated (replicated) on each other 20MHz channels forming the targeted composite channel. Thanks to the duplication of the trigger frame, it is expected that every nearby legacy node (non-HT or 802.11ac nodes) receiving the TF on its primary channel, then sets its NAV to the value specified in the TF frame. This prevents these legacy nodes from accessing the channels of the targeted composite channel during the TXOP.

Based on an AP's decision, the trigger frame TF may define a plurality of resource units (RUs) 310, or "Random RUs", which can be randomly accessed by the nodes of the network. In other words, Random RUs designated or allocated by the AP in the TF may serve as basis for contention between nodes willing to access the communication medium for sending data. A collision occurs when two or more nodes attempt to transmit at the same time over the same RU.

A trigger frame that can be randomly accessed is referred to as a trigger frame for random access (TF-R). A TF-R may be emitted by the AP to allow multiple nodes to perform UL MU (UpLink Multi-User) random access to obtain an RU for their UL transmissions.

The trigger frame TF may also designate Scheduled resource units, in addition or in replacement of the Random RUs. Scheduled RUs may be reserved by the AP for certain nodes in which case no contention for accessing such RUs is needed for these nodes. Such RUs and their corresponding scheduled nodes are indicated in the trigger frame. For instance, a node identifier, such as the Association ID (AID) assigned to each node upon registration, is added in association with each Scheduled RU in order to explicitly indicate the node that is allowed to use each Scheduled RU.

An AID equal to 0 may be used to identify random RUs.

The multi-user feature of OFDMA allows the AP to assign different RUs to different nodes in order to increase competition. This may help to reduce contention and collisions inside 802.11 networks.

Once the nodes have used the RUs to transmit data to the AP, the AP responds with an acknowledgment (not show in the Figure) to acknowledge the data on each RU.

Document IEEE 802.11-15/1105 provides an exemplary random allocation procedure that may be used by the nodes to access the Random RUs indicated in the TF. This random allocation procedure is based on a new backoff counter (OFDMA backoff, or OBO) inside the 802.11ax nodes for allowing a contention in an RU to send data. The OBO determination is further detailed in Figure 7a.

Each node STA1 to STAn is a transmitting node with regards to receiving AP, and as a consequence, each node has an active OFDMA backoff engine for computing and decrementing an OFDMA backoff value (OBO) to be used to contend for access to the random resource units made available by the trigger frames..

The random allocation procedure comprises, for a node of a plurality of nodes having an active OBO backoff value, a first step of determining from the trigger frame the sub-channels or RUs of the communication medium available for contention, a second step of verifying if the value of the active OBO backoff value local to the considered node is not greater than the number of detected-as-available random RUs, and then, in case of successful verification, a third step of randomly selecting a RU among the detected-as-available RUs for sending data. In case of second step is not verified, a fourth step (instead of the third) is performed in order to decrement the OBO backoff value by the number of detected-as-available random RUs.

As shown in the Figure, some Resource Units may not be used (310u) because no node with an OBO backoff value less than the number of available random RUs has randomly selected one of these RUs, whereas some other are collided (as example 310c) because two of these nodes have randomly selected the same random RU. This shows that due to the random

determination of random RUs to access, collision may occur over some RUs, while other RUs may remain free.

The 802.11 ax standard does not specify how the contention parameters should be handled by the nodes. **Figure 9** shows, in thin solid line, how the network efficiency evolves as the number of nodes increases when the OFDMA contention window OCW is kept fixed over time. A maximum efficiency is obtained when the contention window OCW equals the number of random RUs provided in the trigger frames. The network efficiency drastically reduces as the number of nodes increases.

As commonly known from the EDCA protocol, a good solution to raise network efficiency for large numbers of nodes is for each node to double its contention window OCW upon each collision detection, and to set OCW to OCW_{min} upon successful transmission. The corresponding network efficiency is plotted in thick solid line in **Figure 9**. OCW doubling policy guarantees network efficiency increased by about 35% for large numbers of nodes. However, this policy is not adapted to small numbers of nodes because its network efficiency drastically decreases.

Such kinds of handling of contention to random RUs are thus not satisfactory.

There is a need to provide efficient contention to random RUs at the nodes. In this respect, the present invention provides an AP-determined contention policy parameter in the trigger frames based on which the nodes perform selection of one updating scheme from amongst a plurality of different updating schemes in order to update at least one contention parameter driving their contention schemes.

Trigger frames are sent over time by the access point (and thus received by the nodes), each trigger frame reserving a transmission opportunity on at least one communication channel of the wireless network and defining resource units forming the communication channel during the transmission opportunity, including one or more random resource units the nodes access using a contention scheme.

The access point receives data from the nodes over some of the random resource units, thus making it possible for the AP to gather statistics on use, by the nodes, of the random resource units defined in sent trigger frames; and determines a contention policy parameter, for instance representative of a collision rate in the random resource units contended by the nodes. Next, the sent trigger frame may include the determined contention policy parameter to drive the nodes in selecting an updating scheme from a plurality of different updating schemes to update at least one local contention parameter.

Accordingly, the nodes receiving the trigger frames may thus retrieve a contention policy parameter from a received current trigger frame; select, based on a value of the retrieved contention policy parameter, an updating scheme from amongst a plurality of different updating schemes to update at least one contention parameter driving the contention scheme at said node; apply the selected updating scheme to update the contention parameter or parameters;

and then contend for access to a random resource unit using the contention scheme based on the updated contention parameter or parameters.

By selecting an updating scheme based on the contention policy parameter sent by the AP, the latter can directly control the contention of the nodes to the random resource units, in particular to adjust it to the network conditions as the AP can analyze it, contrary to the nodes which do not know a lot about the whole network.

An exemplary wireless network is an IEEE 802.11ac network (and upper versions). However, the invention applies to any wireless network comprising an access point AP 110 and a plurality of nodes 101-107 transmitting data to the AP through a multi-user transmission.

The multi-user transmission preferably relies on the usage of an OFDMA scheme. However, any other scheme defining alternate resource units or more generally alternate channels to be accessed simultaneously through contention by the nodes can also be used.

The invention is especially suitable for data transmission in an IEEE 802.11ax network (and future versions) requiring better use of bandwidth.

An exemplary management of multi-user transmission in such a network has been described above with reference to **Figures 1** to **3**.

Figure 4 schematically illustrates a communication device 400 of the radio network 100, configured to implement at least one embodiment of the present invention. The communication device 400 may preferably be a device such as a micro-computer, a workstation or a light portable device. The communication device 400 comprises a communication bus 413 to which there are preferably connected:

- a central processing unit 411, such as a microprocessor, denoted CPU;
- a read only memory 407, denoted ROM, for storing computer programs for implementing the invention;
- a random access memory 412, denoted RAM, for storing the executable code of methods according to embodiments of the invention as well as the registers adapted to record variables and parameters necessary for implementing methods according to embodiments of the invention; and
- at least one communication interface 402 connected to the radio communication network 100 over which digital data packets or frames or control frames are transmitted, for example a wireless communication network according to the 802.11ax protocol. The frames are written from a FIFO sending memory in RAM 412 to the network interface for transmission or are read from the network interface for reception and writing into a FIFO receiving memory in RAM 412 under the control of a software application running in the CPU 411.

Optionally, the communication device 400 may also include the following components:

- a data storage means 404 such as a hard disk, for storing computer programs for implementing methods according to one or more embodiments of the invention;

- a disk drive 405 for a disk 406, the disk drive being adapted to read data from the disk 606 or to write data onto said disk;
- a screen 409 for displaying decoded data and/or serving as a graphical interface with the user, by means of a keyboard 410 or any other pointing means.

The communication device 400 may be optionally connected to various peripherals, such as for example a digital camera 408, each being connected to an input/output card (not shown) so as to supply data to the communication device 400.

Preferably the communication bus provides communication and interoperability between the various elements included in the communication device 400 or connected to it. The representation of the bus is not limiting and in particular the central processing unit is operable to communicate instructions to any element of the communication device 400 directly or by means of another element of the communication device 400.

The disk 406 may optionally be replaced by any information medium such as for example a compact disk (CD-ROM), rewritable or not, a ZIP disk, a USB key or a memory card and, in general terms, by an information storage means that can be read by a microcomputer or by a microprocessor, integrated or not into the apparatus, possibly removable and adapted to store one or more programs whose execution enables a method according to the invention to be implemented.

The executable code may optionally be stored either in read only memory 407, on the hard disk 404 or on a removable digital medium such as for example a disk 406 as described previously. According to an optional variant, the executable code of the programs can be received by means of the communication network 403, via the interface 402, in order to be stored in one of the storage means of the communication device 400, such as the hard disk 404, before being executed.

The central processing unit 411 is preferably adapted to control and direct the execution of the instructions or portions of software code of the program or programs according to the invention, which instructions are stored in one of the aforementioned storage means. On powering up, the program or programs that are stored in a non-volatile memory, for example on the hard disk 404 or in the read only memory 407, are transferred into the random access memory 412, which then contains the executable code of the program or programs, as well as registers for storing the variables and parameters necessary for implementing the invention.

In a preferred embodiment, the apparatus is a programmable apparatus which uses software to implement the invention. However, alternatively, the present invention may be implemented in hardware (for example, in the form of an Application Specific Integrated Circuit or ASIC).

Figure 5 is a block diagram schematically illustrating the architecture of the communication device or node 400, either the AP 110 or one of the nodes 101 – 107 adapted to carry out, at least partially, the invention. As illustrated, node 400 comprises a physical (PHY) layer block 503, a MAC layer block 502, and an application layer block 501.

The PHY layer block 503 (e.g. a 802.11 standardized PHY layer) has the task of formatting, modulating on or demodulating from any 20 MHz channel or the composite channel, and thus sending or receiving frames over the radio medium used 100, such as 802.11 frames, for instance medium access trigger frames of the TF 330 type to reserve a transmission slot, MAC data and management frames based on a 20 MHz width to interact with legacy 802.11 stations, as well as of MAC data frames of OFDMA type having smaller width than 20 MHz legacy (typically 2 or 5 MHz) to/from that radio medium.

The MAC layer block or controller 502 preferably comprises a MAC 802.11 layer 504 implementing conventional 802.11ax MAC operations, and an additional block 505 for carrying out, at least partially, embodiments of the invention. The MAC layer block 502 may optionally be implemented in software, which software is loaded into RAM 412 and executed by CPU 411.

Preferably, the additional block, referred to contention parameter updating module 505 for managing access onto OFDMA resources (sub-channels), implements the part of the invention that regards node 400, i.e. transmitting operations for a source node, receiving operations for a receiving node, or managing operations for the AP.

For instance and not exhaustively, the operations at the AP may include gathering statistics on use of the Random RUs; computing a collision rate as a ratio between a number of random resource units over which collisions are detected during a monitoring window and a number of random resource units made available to the nodes for contention during the monitoring window; driving the periodical sending of beacon frames, each beacon frame broadcasting network information about the wireless network to the plurality of nodes, wherein a sent beacon frame includes a by-default contention parameter for the contention schemes of the nodes; updating, based on a computed rate of collision in the random resource units contended by the nodes, a local reference lower boundary to be included in a next beacon frame.

The operations at the nodes different from the AP may include using the transmitted contention policy parameter to adjust the contention scheme locally, i.e. to apply the selected updating scheme; periodically receiving the beacon frames mentioned above in order to receive one (or more) by-default contention parameter for the contention scheme, and then setting one or more local contention parameters based on the received by-default contention parameter.

MAC 802.11 layer 504 and contention parameter updating module 505 interact one with the other in order to provide a management of the nodes' contention schemes according to the invention.

On top of the Figure, application layer block 501 runs an application that generates and receives data packets, for example data packets of a video stream. Application layer block 501 represents all the stack layers above MAC layer according to ISO standardization.

Embodiments of the present invention are now illustrated through different flowcharts describing the behaviour at the AP side (**Figures 6a** and **6b**) and at the nodes' side (**Figure 7a** and **7b**).

They are described in the context of IEEE 802.11ax by considering OFDMA sub-channels.

These embodiments supplement the 802.11ax by specifying how the AP can determine contention parameters for the nodes, for instance OCW_{min}; how this parameter is sent to the nodes, either in the trigger frames or in other control frames; and how the nodes updates their contention windows upon collision detection.

In short, the AP appears to be the best place to compute such contention parameters such as OCW_{min} since the AP has an overview of all the network. In such context and as explained below, OCW_{min} for instance may be computed based on the number of nodes waiting for an UL MU OFDMA transmission (i.e. a resource unit) and based on the number of random RUs made available to the nodes in each trigger frame sent. In practice, simulation results show that a simple OCW_{min} equal to a mean number of random RUs made available is satisfactory.

OCW_{min} (which is updated continuously) can thus be transmitted in each beacon frame sent by the AP to the nodes. Indeed, all the nodes can decode such frame, and a dedicated field can be easily added to the beacon frame structure as defined in the 802.11ax standard.

Furthermore, a rough value of OCW_{min} should be enough to define an overall behavior of the nodes.

Thus the nodes can simply update their own OCW_{min} with the information received in each beacon frame.

In addition, the AP transmits a contention policy (CP) parameter in each trigger frame sent to drive the nodes in updating their contention parameters, such as their contention windows OCW. A single bit in the "trigger-dependent common info" field of the trigger frames may be dedicated to this CP parameter, which informs the nodes of an estimated collision rate within the random resource units. Thanks to the CP parameter, each node can drive its own contention window OCW to reach the best network efficiency.

For instance, an appropriate updating procedure is defined as below and includes, upon receiving a trigger frame, proceeding differently whether the CP parameter is 0 (low collision rate) or 1 (high collision rate).

In case of low collision rate, OCW_{min} may be set by the node to the number of random RUs of the current trigger frame, and OCW is set to OCW_{min}, avoiding OCW doubling upon transmission failure.

In case of high collision rate, OCW_{min} may be kept unchanged while, if the last MU UL transmission failed, OCW is doubled, and if the last MU UL transmission succeeded, OCW is reset to OCW_{min}.

The nodes thus dynamically refine their OCW and OCW_{min} to react as soon as possible to channel condition changes, as indicated by the AP through the CP parameter.

As the OCW doubling should be preferably implemented, the default value of the CP parameter is 1 (indicating a high collision rate).

Figure 10 shows in thick solid line the network efficiency thus obtained. The mechanism proposed by the present invention thus provides improved network efficiency.

Figure 6a illustrates, using a flowchart, general steps for the AP to build and send a beacon frame including a new OCW_{min} value, the lower boundary of the selection range [OCW_{min}, OCW_{max}] from which the contention window OCW is selected by the nodes. In variant any other contention parameter, such as OCW_{max} or OCW, can be transmitted.

The 802.11 standard defines a beacon frame as a frame broadcasting the 802.11 network information to all stations of the network. The beacon frame is periodically transmitted, approximately each 100 milliseconds, during which a plurality of network accesses are made by the nodes or the AP.

As a reminder, OCW_{min} can be adjusted upon each MU UL OFDMA transmission or only after a predefined set of MU UL OFDMA transmissions. This value has a big influence on the RU efficiency metric. However, it is difficult to evaluate a precise OCW_{min} value because the AP is not able to determine the number of the nodes actually participating the MU UL OFDMA transmissions. To avoid bandwidth consuming, it is proposed to transmit a new OCW_{min} value (i.e. an update of the OCW_{min} value) upon each new beacon frame sending.

As this value is sent by the AP to the nodes as a reference value for the latter, the reference lower boundary is noted $OCW_{min,ref}$.

When a beacon frame has to be sent and thus when preparing a new beacon frame to be sent, a collision rate is computed from OFDMA statistics at step 651.

OFDMA statistics are gathered at the end of each MU UL OFDMA transmission from the nodes during previous TFs: the AP collects and analyses the number of RUs that are collided, unused and well used for each previous TF. The number of available random RUs per trigger frame is also stored to compute a mean value of available random RUs. The statistics may be saved for a sliding monitoring period. All the values are stored as OFDMA statistics (see **Figure 6b** – step 620).

Steps 652 to 680 make it possible for the AP to update, based on a computed rate of collision in the random resource units contended by the nodes, a local reference lower boundary $OCW_{min,ref}$ to be included in the next beacon frame.

If the collision rate is greater than an upper threshold (for instance 0.3, test 652), the local reference lower boundary $OCW_{min,ref}$ value is doubled at step 660. This is because when the collision rate is high, many nodes want to competitively participate to the MU UL OFDMA transmissions. So increasing the $OCW_{min,ref}$ value will increase the OBO values randomly selected by the nodes if based on the transmitted $OCW_{min,ref}$ value. As a

consequence, the access delay will be increased, and fewer nodes will be allowed to select random RUs for the next MU UL OFDMA transmissions.

On the other hand, the local reference lower boundary is kept unchanged if the computed collision rate is between a lower threshold and the upper threshold (test 670). This is because the current $OCW_{min,ref}$ value seems appropriate and may remain constant (step 671).

However, the local reference lower boundary may be reset to a by-default value if the computed collision rate is below the lower threshold, at step 680. The by-default value may be a mean number of random resource units made available to the nodes in trigger frames sent, e.g. over a monitoring window (e.g. 1 or 2 or more up to 5 trigger frames). This is because when the collision rate is low, the number of unused random RUs is high. So to improve the RU efficiency, it is worth minimizing the $OCW_{min,ref}$ value. In that case, the time delay to RU access is reduced for the nodes willing to gain a MU UL OFDMA transmission.

In a slight variant, the upper threshold and the lower threshold are one and the same threshold, meaning that step 671 is never performed: when the computed collision rate is higher than the threshold, the $OCW_{min,ref}$ value is set to a by-default value; otherwise the OCW_{min} value is doubled.

Next to steps 660, 671 and 680, steps 690 and 691 are in charge of building and broadcasting the beacon frame including the updated reference lower boundary $OCW_{min,ref}$ value to all the nodes of the network.

Thus the nodes periodically receive a new reference lower boundary $OCW_{min,ref}$ value (or any other by-default contention parameter sent by the AP through the beacon frames) as a by-default contention parameter for their local contention schemes.

Figure 7a illustrates, using a flowchart, general steps for the nodes to determine the OCW_{min} value (or any other by-default contention parameter) received from the AP through a beacon frame and to set accordingly local contention parameters for the next random access procedure onto OFDMA Resource Unit in the context of ML UL OFDMA transmission. Thus the process of **Figure 7a** is performed by each node.

Upon the reception of a new beacon frame from the AP (step 700), the node sets its local lower boundary OCW_{min} of the selection range [OCW_{min}, OCW_{max}] to the $OCW_{min,ref}$ value as decoded (step 701) from the received beacon frame. This is step 702.

Next, the current OCW value of the node is also reset to OCW_{min} (step 703).

These values will be used for the next random generation of the OBO value (random selection from range [0,OCW] where contention window OCW is in the selection range [OCW_{min}, OCW_{max}]).

Figures 6b illustrates, using a flowchart, general steps for the AP side to build and send a trigger frame including a contention policy parameter as briefly introduced above, to drive the nodes in selecting an updating scheme from a plurality of different updating schemes to update at least one local contention parameter. The process waits for the end of each MU UL OFDMA transmission.

Upon the end of a MU UL OFDMA transmission (test 610), the AP gathers OFDMA statistics on use, by the nodes, of the random resource units of this transmission, and then analyses the number of random RUs that are collided, unused and well used. The number of available random RUs per trigger frame is also stored to compute a mean value of available random RUs.

Examples of OFDMA statistics that may be produced as the successive MU UL OFDMA transmissions occur include:

a collision ratio between the number of collided random RUs and the total number of random RUs made available to the nodes during the analysis or monitoring window (e.g. couples of trigger frames),

an unuse ratio between the number of unused RUs and the total number of available random RUs, and/or

an efficiency ratio between the number of the non-collided and allocated random RUs and the total number of available random RUs. A non-collided and allocated random RU means that only one node randomly selected this random RU when its own OFDMA backoff reached zero, and the data transmission inside this selected random RU was well received by the AP.

Preferably, these ratios are evaluated over a sliding monitoring window made of a set of trigger frames.

Next, step 630 is in charge of computing the contention policy parameter to be inserted in the next trigger frame. It is determined based on the OFDMA statistics, and preferably determined based on the computed collision rate. Thus, the contention policy parameter can be representative of a collision rate in the random resource units contended by the nodes.

In a first embodiment, the contention policy parameter includes the computed collision rate. That is the CP parameter can be the real value of the collision rate that is the ratio between the number of collided random RUs and the total number of random RUs made available to the nodes for contention.

In another embodiment, the CP parameter can identify a collision profile from a set of collision profiles (a collision profile is made of one or more predefined values of the collision rate) to reduce the number of bits needed to inform the nodes. The collision profile set in the CP parameter is the one matching with the computed collision rate.

In another embodiment, a single bit can be used. For instance it is set to 1 when the collision rate is upper than a predefined threshold, noted THR; otherwise it is set to 0. In other words, the CP parameter is made of a single bit which takes a first value if the computed collision rate is below a predefined threshold and takes a second value if the computed collision rate is above the predefined threshold. Note that a default value for the CP parameter is 1, used for instance when the AP has no relevant OFDMA statistics (e.g. start of the wireless network, trigger frames too old, etc.).

Once the CP parameter has been determined/computer, it is inserted, at step 640, in the next trigger frame to be sent.

Figure 8 illustrates the structure of a trigger frame as defined in the 802.11ax draft standard.

The trigger frame 800 is composed of a dedicated field 810 called Common Info Field. This field contains a "Trigger dependent Common info" field 830 in which the CP parameter can be inserted.

The other fields of the trigger frame are defined in the 802.11ax standard.

Next steps 641 and 642 are in charge of building and sending the trigger frame to the nodes of the 802.11 network.

Thus the nodes receive one or more trigger frames from the AP, which include such a CP parameter, the value of which evolves over time as the gathered OFDMA statistics evolve.

Figure 7b illustrates, using a flowchart, general steps for any of the nodes to update one or more contention parameters, preferably the OCW value and/or the OCW_{min} value, based on the received trigger frames. The updated parameters are preferably used for the next random access procedure onto OFDMA Resource Unit in the context of MU UL OFDMA transmission.

A set of random resource units (RUs) are available upon the reception of a random trigger frame (TF-R) at step 710. As shown in **Figure 8**, the CP parameter can be retrieved from the received TF-R by reading the "Trigger dependent Common Info" field 820.

As indicated above, the CP parameter is preferably representative of a collision rate computed by the access point over past random resource units defined by trigger frames preceding the received current trigger frame.

If the CP parameter is lower than a predefined threshold (test 711), preferably THR defined above, for instance 0.3 (or the one-bit CP parameter is 0), the AP has indicated to the nodes that, as a result of the previous MU UL OFDMA transmissions, there is more unused random RUs than collided random RUs. So it may not be worth increasing the delay to grant a random RU to the node and to try decreasing the collision rate. Decreasing the delay to grant a random RU means that the OBO and the OCW values of the node are decreased.

Thus, in such a situation a first updating scheme is selected by the node from two or more updating schemes available. One exemplary execution of the selected first updating scheme is shown through steps 720 to 741.

Optionally the OCW_{min} value is set to a default value at step 720, which default value may be the number of available random RUs defined in the just received trigger frame or the $OCW_{min,ref}$ value of the last received beacon frame (see step 702). This OCW_{min} value will be used for the next OBO generation.

If an OBO is currently decreasing, i.e. the OBO value is non-zero at that time (test 730), an optional step 731 may be implemented to update the current backoff value OBO and

the contention window OCW. This update may be based on the number of random resource units defined by the received current trigger frame. For instance, each of the contention window OCW and the non-zero current backoff value OBO is multiplied by a ratio between the number $NbrR\text{-}RUs_{(n-1)}$ of random resource units defined by the last trigger frame TF(n-1) and the number $NbrR\text{-}RUs_{(n)}$ of random resource units defined by the received current trigger frame TF(n):

$$OCW_{(n)} = (NbrR\text{-}RUs_{(n-1)} / NbrR\text{-}RUs_{(n)}) * OCW_{(n-1)}$$

$$OBO_{(n)} = (NbrR\text{-}RUs_{(n-1)} / NbrR\text{-}RUs_{(n)}) * OBO_{(n-1)}$$

with *n* is the index of the currently received trigger frame and *(n-1)* the index of the previously received trigger frame.

On the other hand, if a new OBO value has to be randomly generated from the contention window (test 730), the OCW value is set to a by-default value, for instance the current OCW_{min} value (possibly previously set at step 720). This is step 740.

A new OBO value is next generated by randomly selecting it from range [0, OCW] once OCW has been updated at step 740. This is step 741.

Next to the updating of the contention parameters of the node, the node can contend, based on the updated contention parameter or parameters, for access to a random resource unit defined by the received current trigger frame. The current backoff value OBO is decremented upon receiving each of the trigger frames, by the number of random resource units defined by the received trigger frame. This is step 780.

Next, if the OBO value is equal or lower to 0 (test 781), a random RU can be randomly selected from among the set of available random RUs of the currently received trigger frame and a MU UL OFDMA transmission can be initiated by the node to transmit some data to the AP through the selected random RU. This is step 782.

On the other hand, if the OBO value is greater than 0, the current OBO value is stored in memory, so that it can be used as the current OBO value when a next random trigger frame is received.

Back to test 711, if the CP parameter is greater than the predefined threshold, the AP has indicated to the nodes that, as a result of the previous MU UL OFDMA transmissions, there are less unused random RUs than collided random RUs. So it may be worth increasing the delay for accessing the medium for the MU UL OFDMA transmissions, to try decreasing the collision rate. Indeed, decreasing the delay to grant a random RU means that the OBO and the OCW values of the node are decreased, and thus the node accesses more rarely random RUs.

Thus, in such a situation a second updating scheme is selected by the node from the updating schemes available. One exemplary execution of the selected second updating scheme is shown through steps 750 to 776.

Optionally, the OCW_{min} value is updated to reflect changes in the number of random RUs now available to the nodes for contention. Indeed, as this number varies, the efficiency of the running contention scheme also varies. Thus there may be a need to adjust it.

At optional step 750, the lowest boundary OCW_{min} is updated based on the number $NbrR\text{-}RUs_{(n)}$ of random resource units defined by the received current trigger frame.

Preferably, the current OCW_{min} value is multiplied by a ratio between the number $NbrR\text{-}RUs_{(n-1)}$ of random resource units defined by the last received trigger frame and the number $NbrR\text{-}RUs_{(n)}$ of random resource units defined by the received current trigger frame:

$$OCW_{min}(n) = (NbrRUs_{(n-1)} / NbrRUs_{(n)}) * OCW_{min}(n-1)$$

It should be noted that in case the current trigger frame is the first one following the last received beacon frame, the current OCW_{min} value has been set to $OCW_{min,ref}$ as indicated by the beacon frame (see step 702). In such a situation, it may be worth keeping OCW_{min} unchanged at step 750 because the OCW_{min} value just received from the AP is more relevant at that time. However, if the current trigger frame is quite far (in time) from the last received beacon frame, it may be decided to perform the updating in any case.

If an OBO is currently decreasing, i.e. the current OBO value is non-zero at that time (test 760) an optional step 761, similar to step 731 described above, can be performed ti update the current backoff value OBO and the contention window OCW.

Next to step 761, contention to the random RUs can be performed through steps 780-782.

On the other hand, if a new OBO value has to be randomly generated from the contention window (test 760), the OCW value is updated depending on success or failure of a last MU UL OFDMA transmission of data by said node to the access point over an accessed random resource unit.

If the last MU UL OFDMA transmission was succeeded, the OCW value is set to the lowest boundary OCW_{min} of the selection range from which the contention window OCW is selected. This is step 775. In addition, a new OBO value is generated by randomly selecting it from range [0, OCW]. This is step 776

On the other hand, it the last MU UL OFDMA transmission was not succeeded, the OCW value is updated at step 771 in the same way as done in step 731 or 761: $OCW_{(n)} = (NbrR\text{-}RUs_{(n-1)} / NbrR\text{-}RUs_{(n)}) * OCW_{(n-1)}$.

Next, the new OCW value is multiplied by a multiplying factor, for instance it is doubled, at step 772.

In other words, steps 771 and 772 multiply the current contention window OCW by a multiplying factor in case of transmission failure, wherein the multiplying factor is twice a ratio between the number of random resource units defined by the received trigger frame immediately preceding the current trigger frame and the number of random resource units defined by the received current trigger frame.

The adaptation of OCW to the number of random RUs makes it possible for the node to immediately react to a change of random RUs made available to the competing nodes.

Also, the OCW doubling action allows the node to react immediately on its failed MU UL transmissions.

Next to step 772 or 776, contention to the random RUs can be performed through steps 780-782..

Note that the nodes may not have data to transmit to the AP. However, for them to be in a good configuration for contention when new data are to be transmitted, they should follow the same updating of contention parameters driven by the AP, as the other nodes.

Thus, tests 730 and 760 may determine whether or not a new OBO value is needed. This only happens if no current OBO value is running and that data are to be transmitted to the AP.

In case of negative determination (a current OBO value is running or the node has no data to transmit), step 731 or 761 is performed. In case the node has no data to transmit, this step does not update OBO, of course.

As a consequence thanks to steps 720 (or 750) and 731 (or 761), the node updates at least one of its contention parameters, here OCW and/or OCW_{min}, upon receiving the current trigger frame (embedding a CP parameter) even if the node does not seek to contend for access to any of the random RUs of this current trigger frame.

However, the node will contend, based on the updated contention parameter or parameters, for access to random resource units defined by a next trigger frame. And for each trigger frame between the current trigger frame and this next trigger frame, the node may each time update again these contention parameters.

In other words, the node retrieves a second contention policy parameter from each following trigger frame up to this “next” trigger frame; selects, based on a value of the retrieved second contention policy parameter, a second updating scheme from amongst the plurality of different updating schemes; and applies the selected second updating scheme to update again the updated contention parameter or parameters, before contending for access to the random resource unit based on the twice (or more) updated contention parameter or parameters.

Although the present invention has been described hereinabove with reference to specific embodiments, the present invention is not limited to the specific embodiments, and modifications will be apparent to a skilled person in the art which lie within the scope of the present invention.

Many further modifications and variations will suggest themselves to those versed in the art upon making reference to the foregoing illustrative embodiments, which are given by way of example only and which are not intended to limit the scope of the invention, that being determined solely by the appended claims. In particular the different features from different embodiments may be interchanged, where appropriate.

In the claims, the word “comprising” does not exclude other elements or steps, and the indefinite article “a” or “an” does not exclude a plurality. The mere fact that different features are recited in mutually different dependent claims does not indicate that a combination of these features cannot be advantageously used.

CLAIMS

1. A wireless communication method in a wireless network comprising an access point and a plurality of nodes, the method comprising, at one of said nodes:

receiving trigger frames from the access point, each trigger frame reserving a transmission opportunity on at least one communication channel of the wireless network and defining resource units forming the communication channel during the transmission opportunity, including one or more random resource units the nodes access using a contention scheme;

periodically receiving a beacon frame from the access point, each beacon frame broadcasting network information about the wireless network to the plurality of nodes, wherein a received current beacon frame includes a contention parameter for the contention scheme of said node;

contending for access to a random resource unit using the contention scheme based on the contention parameter included in the beacon frame.

2. The method of Claim 1, further comprising, at one of said nodes:

updating at least one contention parameter using the contention parameter included in the beacon frame for driving the contention scheme at said node; and

contending for access to a random resource unit using the contention scheme based on the updated contention parameter or parameters.

3. The method of Claim 1, wherein the contention scheme at said node decrements a current backoff value of a backoff counter initially selected from a contention window, the contention window is selected from a selection range, and the contention parameter included in the received current beacon frame includes a reference lower boundary for the selection range or includes a reference higher boundary for the selection range or includes the contention window.

4. The method of Claim 3, further comprising, at said node upon receiving the current beacon frame, setting the lower boundary of the selection range to the reference lower boundary included in the received current beacon frame.

5. The method of Claim 4, further comprising, at said node upon receiving the current beacon frame, setting the contention window to the reference lower boundary included in the received current beacon frame.

6. The method of Claim 1, wherein each received beacon frame includes a reference lower boundary.

7. The method of Claim 1, wherein the contention scheme at said node decrements a current backoff value of a backoff counter initially selected from a contention window and triggers access to a random resource unit upon the current backoff value reaching a target value.

8. A wireless communication method in a wireless network comprising an access point and a plurality of nodes, the method comprising, at the access point:

sending trigger frames, each trigger frame reserving a transmission opportunity on at least one communication channel of the wireless network and defining resource units forming the communication channel during the transmission opportunity, including one or more random resource units the nodes access using a contention scheme;

receiving data from the nodes over some of the random resource units;

determining a contention parameter;

periodically sending a beacon frame, each beacon frame broadcasting network information about the wireless network to the plurality of nodes, wherein a sent beacon frame includes the contention parameter for the contention schemes of the nodes.

9. The method of Claim 8, wherein the contention schemes at the nodes are based on respective contention windows, and the contention parameter included in the sent beacon frame includes a reference lower boundary to be used by nodes as a lower boundary of a selection range from which they select their respective contention window, or includes a reference higher boundary to be used by nodes as a higher boundary of a selection range from which they select their respective contention window, or includes the contention window to be used as respective contention window.

10. The method of Claim 9, further comprising, at the access point, updating, based on a computed rate of collision in the random resource units contended by the nodes, a local reference lower boundary to be included in a next beacon frame.

11. The method of Claim 10, wherein the collision rate is computed upon preparing a new beacon frame to be sent.

12. The method of Claim 10, wherein the local reference lower boundary is doubled if the computed collision rate is above an upper threshold.

13. The method of Claim 12, wherein the local reference lower boundary is reset to a by-default value if the computed collision rate is below a lower threshold.

14. The method of Claim 13, wherein the upper threshold and the lower threshold are one and the same threshold.

15. The method of Claim 13, wherein the local reference lower boundary is kept unchanged if the computed collision rate is between the lower and upper thresholds.

16. The method of Claim 13, wherein the by-default value is a mean number of random resource units in trigger frames sent.

17. The method of Claim 1 or 8, wherein the communication channel is a 20 MHz channel according to the 802.11ax standard.

18. A non-transitory computer-readable medium storing a program which, when executed by a microprocessor or computer system in a device, causes the device to perform the method of Claim 1 or 8.

19. A communication device in a wireless network comprising an access point and a plurality of nodes, the device comprising at least one microprocessor configured for carrying out steps of:

receiving trigger frames from the access point, each trigger frame reserving a transmission opportunity on at least one communication channel of the wireless network and defining resource units forming the communication channel during the transmission opportunity, including one or more random resource units the nodes access using a contention scheme;

periodically receiving a beacon frame from the access point, each beacon frame broadcasting network information about the wireless network to the plurality of nodes, wherein a received current beacon frame includes a contention parameter for the contention scheme of said node;

contending for access to a random resource unit using the contention scheme based on the contention parameter included in the beacon frame

20. An access point in a wireless network comprising an access point and a plurality of nodes, the access point comprising at least one microprocessor configured for carrying out steps of:

sending trigger frames, each trigger frame reserving a transmission opportunity on at least one communication channel of the wireless network and defining resource units forming the communication channel during the transmission opportunity, including one or more random resource units the nodes access using a contention scheme;

receiving data from the nodes over some of the random resource units;

determining a contention parameter;

periodically sending a beacon frame, each beacon frame broadcasting network information about the wireless network to the plurality of nodes, wherein a sent beacon frame includes the contention parameter for the contention schemes of the nodes.

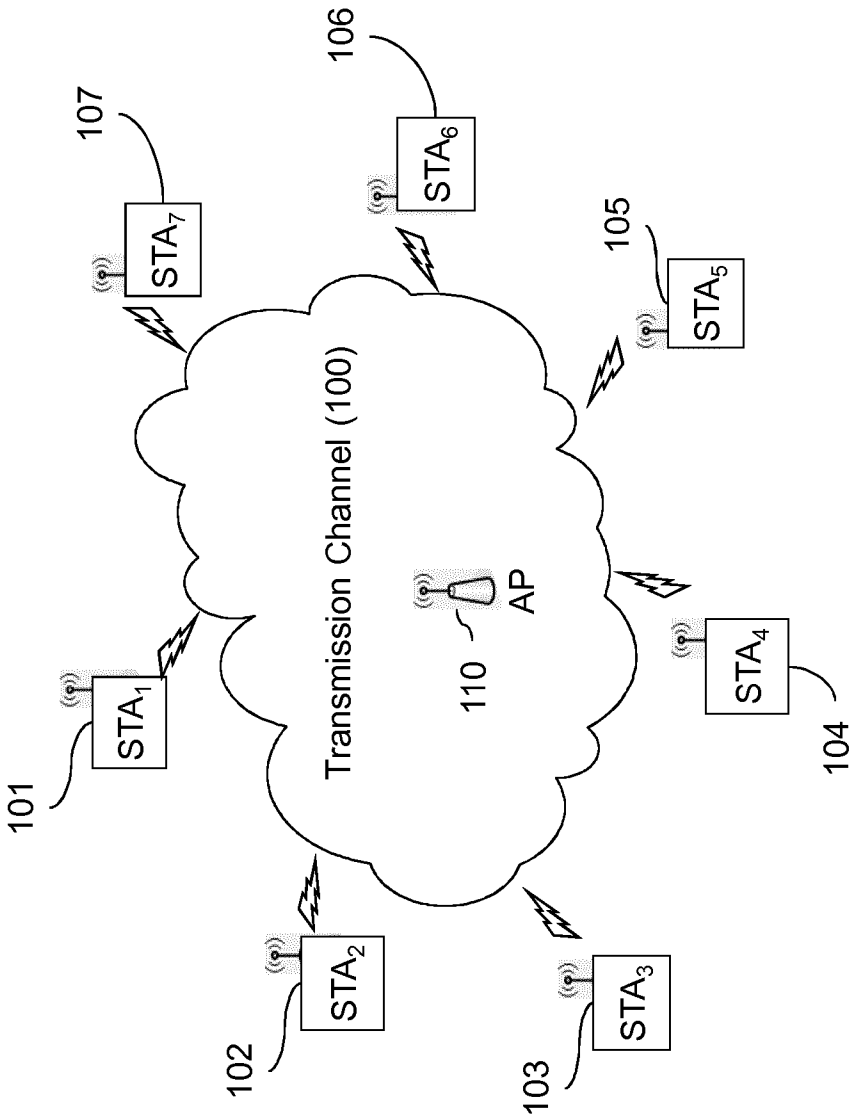

Transmission Channel (100)
AP
110
STA1
101
STA2
102
STA3
103
STA4
104
STA5
105
STA6
106
STA7
107

Fig. 1

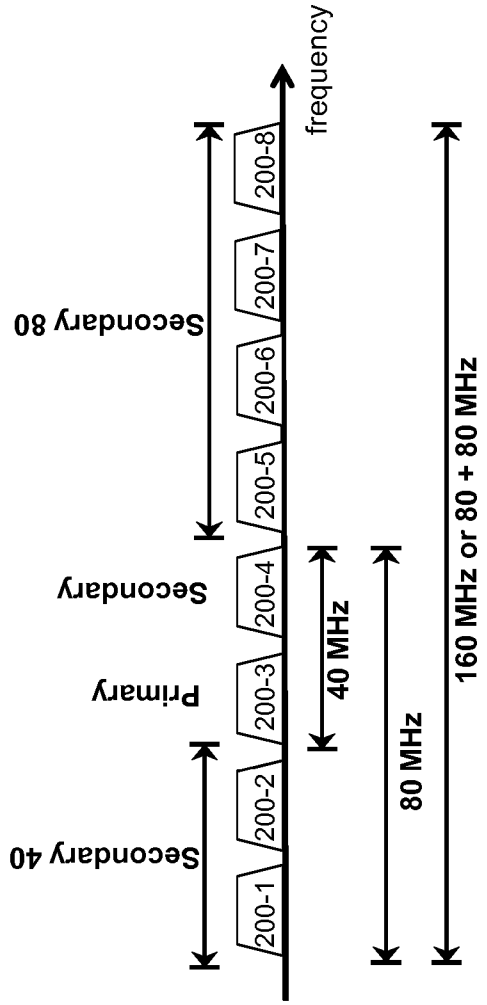

frequency
200-1
200-2
200-3
200-4
200-5
200-6
200-7
200-8
Secondary 40
Primary
Secondary
Secondary 80
40 MHz
80 MHz
160 MHz or 80 + 80 MHz

Fig. 2

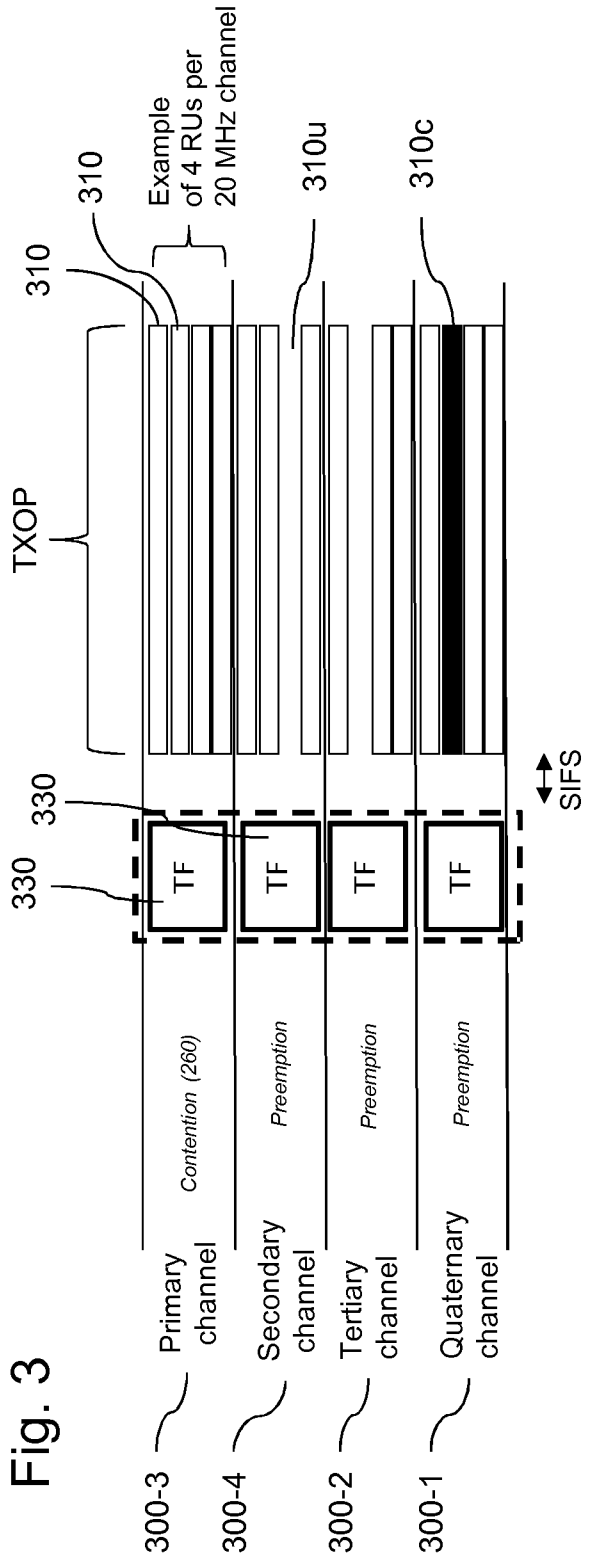

Example of 4 RUs per 20 MHz channel
310
310
310u
310c
TXOP
330
330
TF
TF
TF
TF
SIFS
Contention (260)
Preemption
Preemption
Preemption
Primary channel
Secondary channel
Tertiary channel
Quaternary channel
300-3
300-4
300-2
300-1

Fig. 3

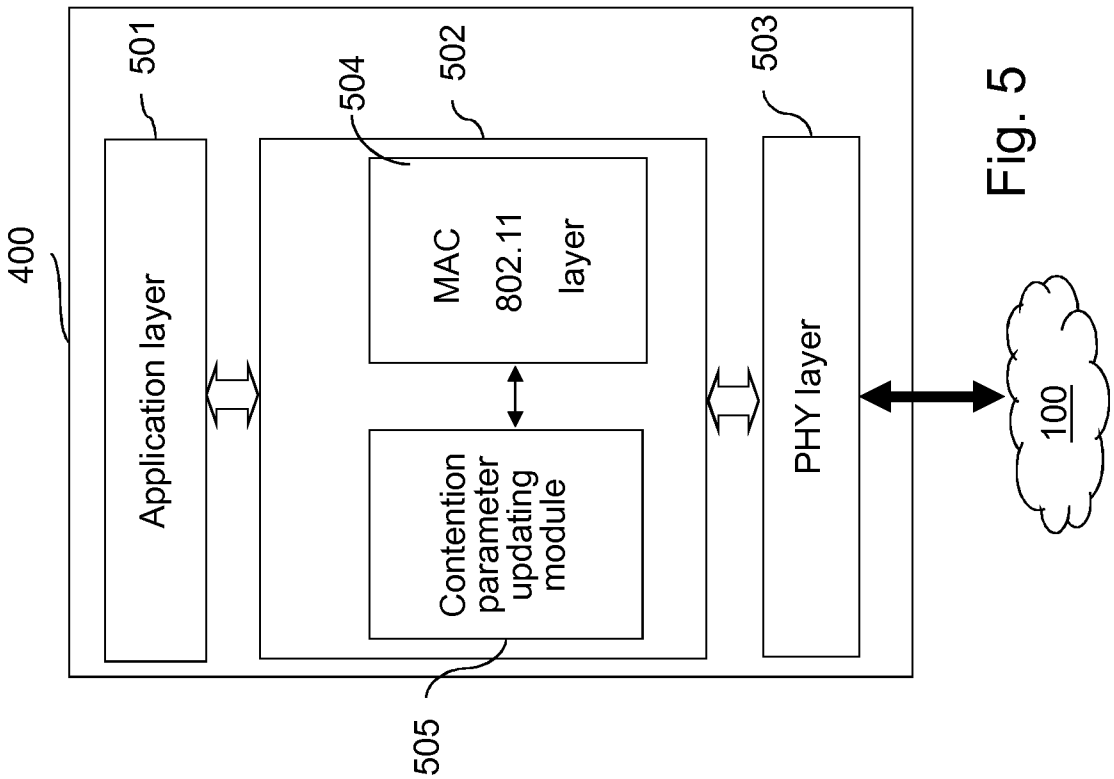

400
501
504
502
503
Application layer
MAC 802.11 layer
Contention parameter updating module
PHY layer
505
100

Fig. 5

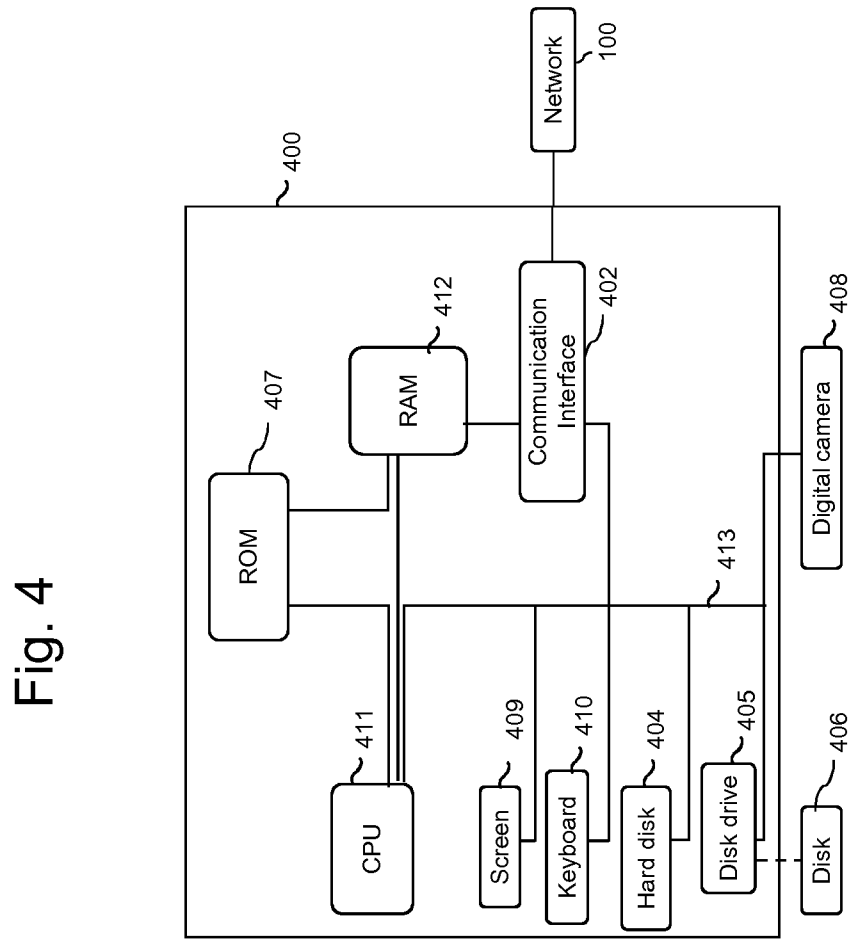
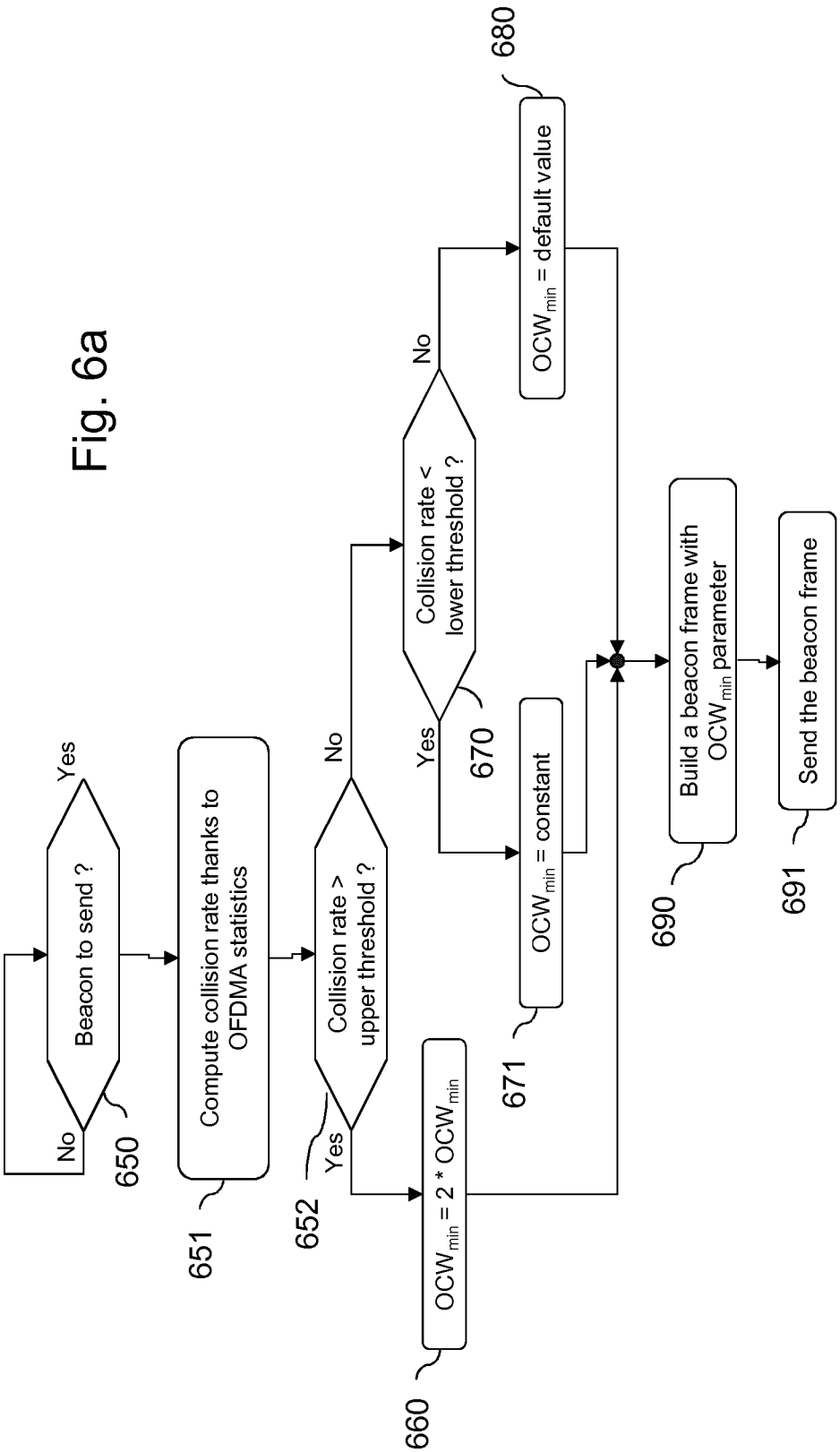

Network
100
400
Communication Interface
402
RAM
412
ROM
407
Digital camera
408
413
CPU
411
Screen
409
Keyboard
410
Hard disk
404
Disk drive
405
Disk
406

Fig. 4

Fig. 6a


Beacon to send ?
Yes
No
650
Compute collision rate thanks to OFDMA statistics
651
Collision rate > upper threshold ?
No
Yes
652
OCW_min = 2 * OCW_min
660
Collision rate < lower threshold ?
No
Yes
670
OCW_min = constant
671
OCW_min = default value
680
Build a beacon frame with OCW_min parameter
690
Send the beacon frame
691

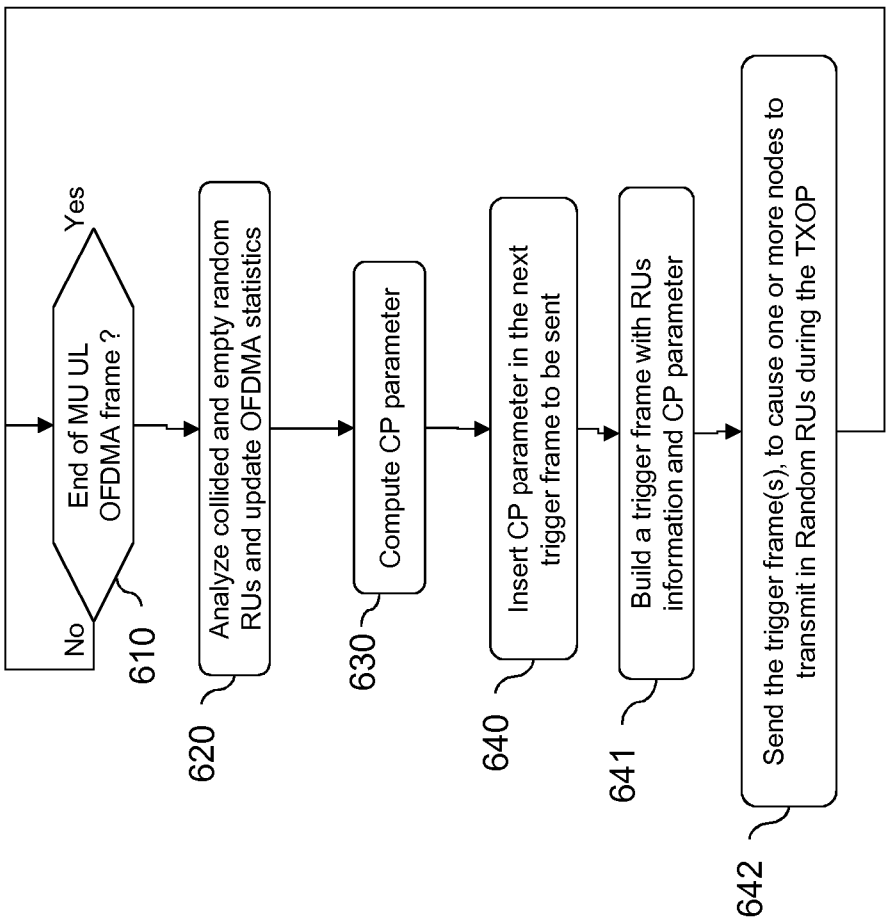

End of MU UL OFDMA frame ?
Yes
No
610
Analyze collided and empty random RUs and update OFDMA statistics
620
Compute CP parameter
630
Insert CP parameter in the next trigger frame to be sent
640
Build a trigger frame with RUs information and CP parameter
641
Send the trigger frame(s), to cause one or more nodes to transmit in Random RUs during the TXOP
642

Fig. 6b

Fig. 7a

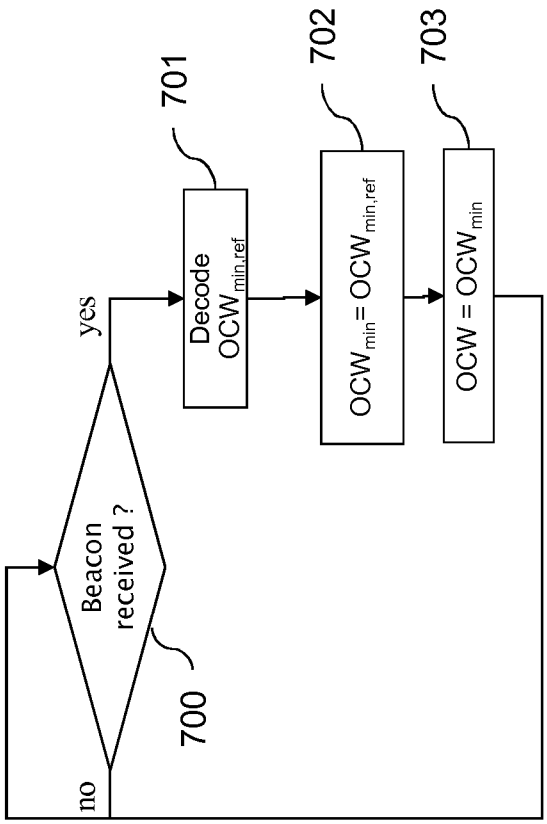

Beacon received ?
yes
no
Decode OCW min,ref
OCW min = OCW min,ref
OCW = OCW min
700
701
702
703

Fig. 7b

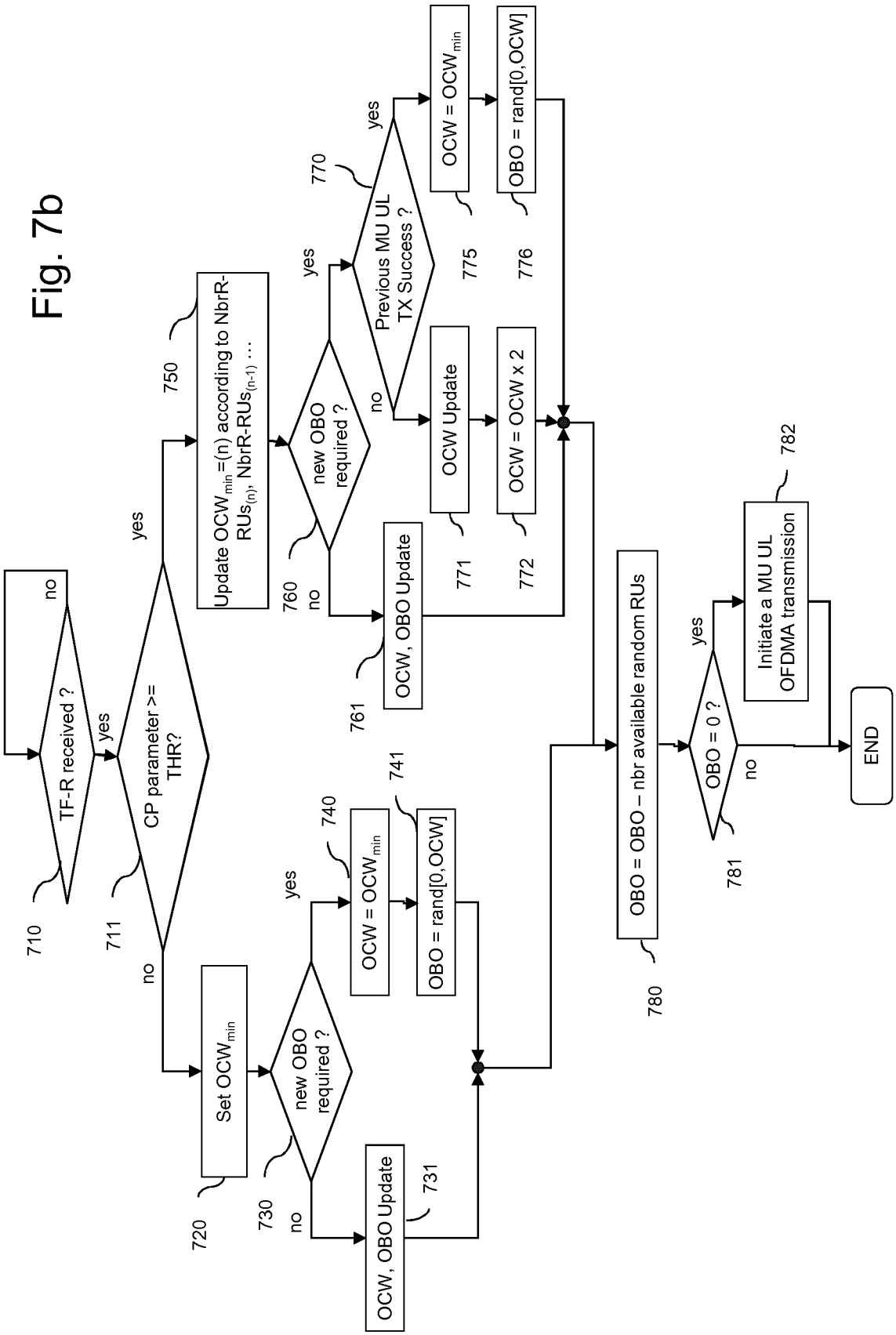

TF-R received ?
no
yes
710
CP parameter >= THR?
yes
711
no
Update OCW$_{min}$=(n) according to NbrR-RUs$_{(n)}$, NbrR-RUs$_{(n-1)}$ …
750
Set OCW$_{min}$
720
new OBO required ?
730
yes
no
OCW = OCW$_{min}$
740
OBO = rand[0,OCW]
741
OCW, OBO Update
731
new OBO required ?
760
yes
no
Previous MU UL TX Success ?
770
yes
no
OCW = OCW$_{min}$
775
OBO = rand[0,OCW]
776
OCW Update
771
OCW = OCW x 2
772
OCW, OBO Update
761
OBO = OBO – nbr available random RUs
780
OBO = 0 ?
781
yes
no
Initiate a MU UL OFDMA transmission
782
END

Fig. 8

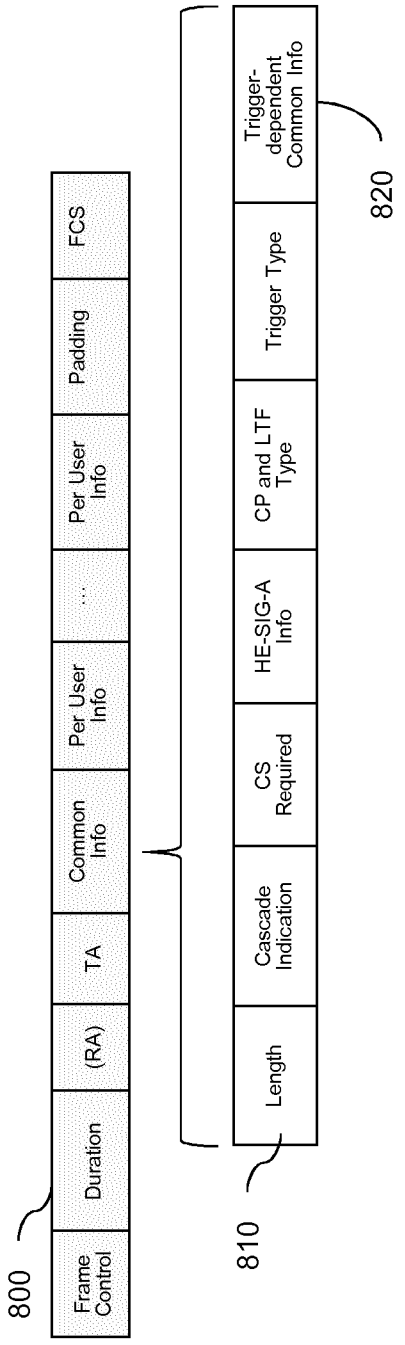

Frame Control
Duration
(RA)
TA
Common Info
Per User Info
...
Per User Info
Padding
FCS
800
Length
Cascade Indication
CS Required
HE-SIG-A Info
CP and LTF Type
Trigger Type
Trigger-dependent Common Info
810
820

Fig. 9

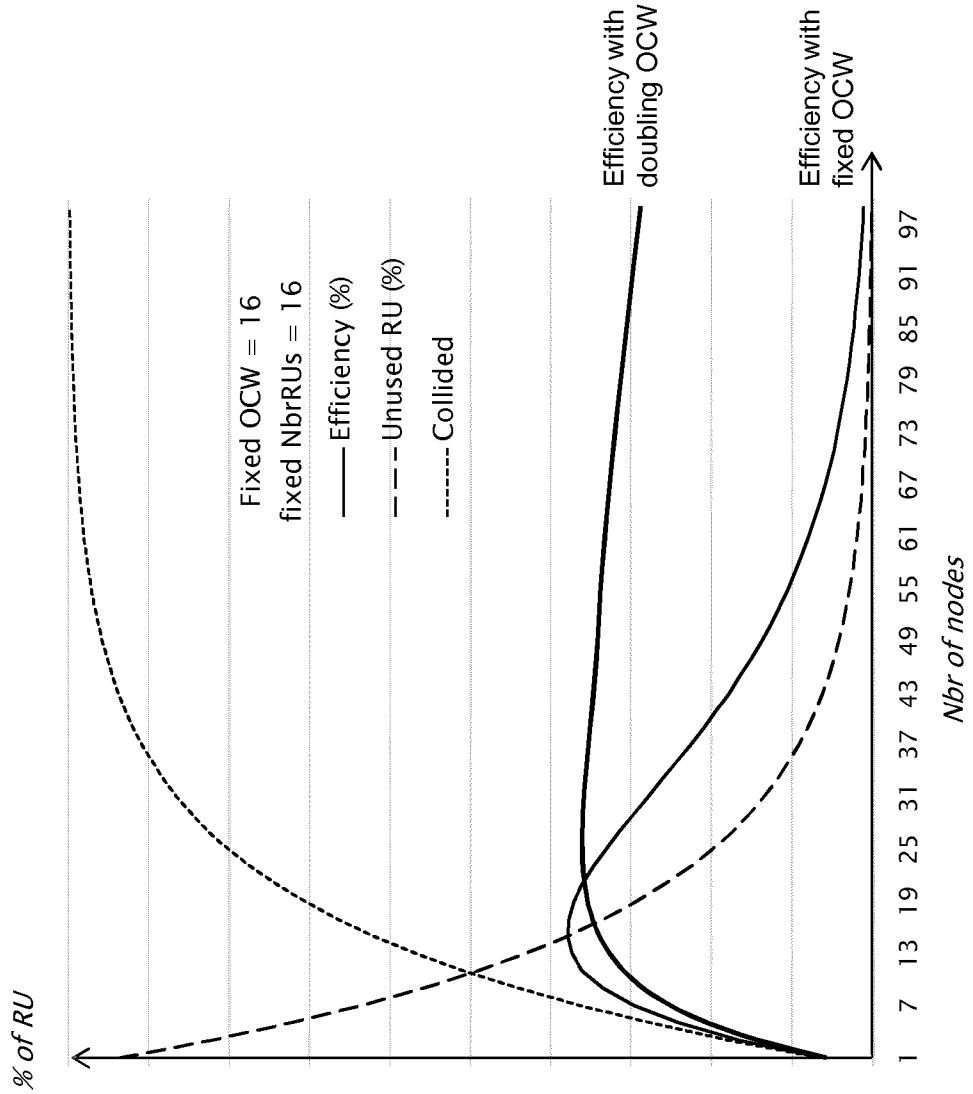
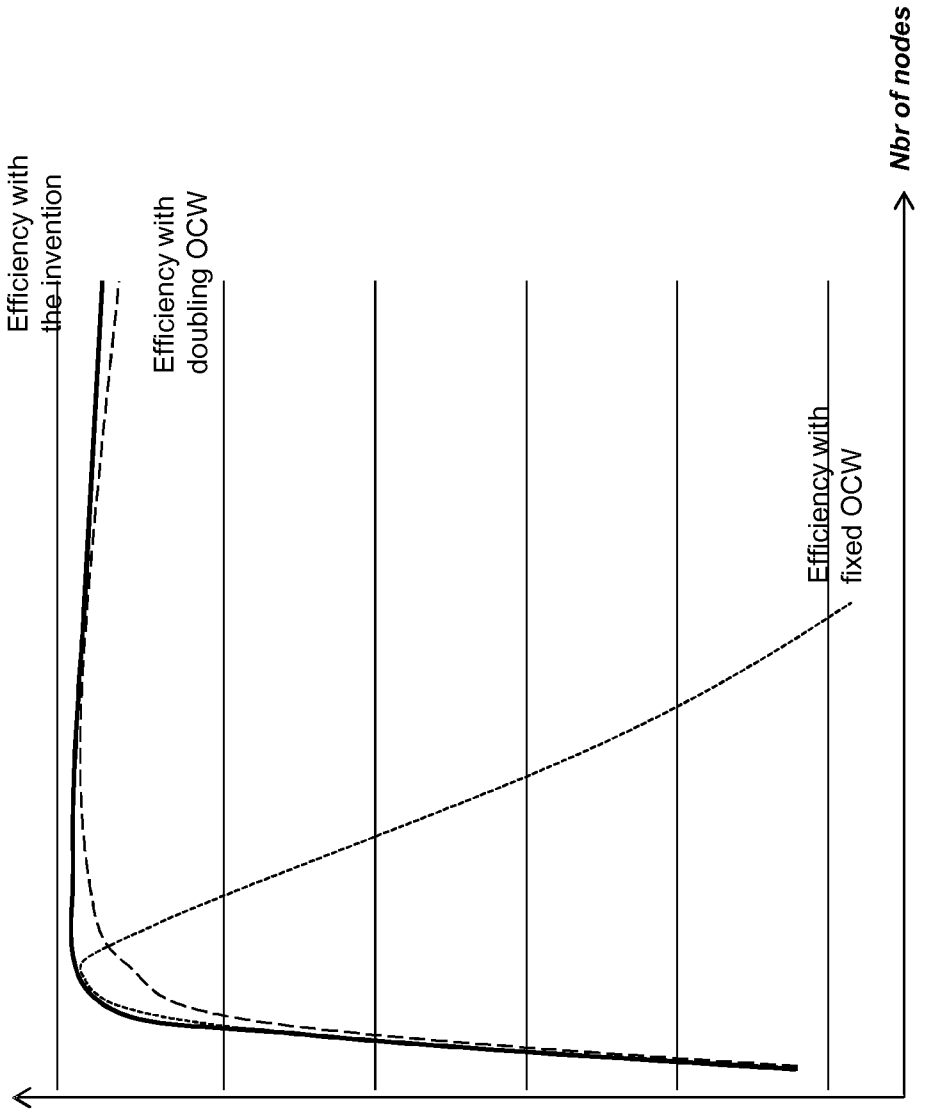

% of RU
Fixed OCW = 16
fixed NbrRUs = 16
Efficiency (%)
Unused RU (%)
Collided
Efficiency with doubling OCW
Efficiency with fixed OCW
1 7 13 19 25 31 37 43 49 55 61 67 73 79 85 91 97
Nbr of nodes

Fig. 10


Efficiency with the invention
Efficiency with doubling OCW
Efficiency with fixed OCW
Nbr of nodes

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/059490

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W74/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04W H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	RUSSELL HUANG (MEDIATEK): "Triggered OFDMA Random Access Observations ; 11-15-1137-01-00ax-triggered-ofdma-random-access-observations", IEEE DRAFT; 11-15-1137-01-00AX-TRIGGERED-OFDMA-RANDOM-ACCESS-OBSERVATIONS, IEEE-SA MENTOR, PISCATAWAY, NJ USA, vol. 802.11ax, no. 1, 14 September 2015 (2015-09-14), pages 1-14, XP068098405, [retrieved on 2015-09-14] page 9 page 11 - page 12 page 14 ----- -/--	1-20

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 July 2017	19/07/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Cortés Gómez, F

1

Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	STEPHANE BARON (CANON): "Traffic priority for random Multi User Uplink OFDMA ; 11-15-1280-01-00ax-traffic-priority-for-random-multi-user-uplink-ofdma", IEEE DRAFT; 11-15-1280-01-00AX-TRAFFIC-PRIORITY-FOR-RANDOM-MULTI-USER-UPLINK-OFDMA, IEEE-SA MENTOR, PISCATAWAY, NJ USA, vol. 802.11ax, no. 1, 9 November 2015 (2015-11-09), pages 1-24, XP068099213, [retrieved on 2015-11-09] page 2 page 4 page 10 page 12 page 15 page 17 -----	1-20
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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