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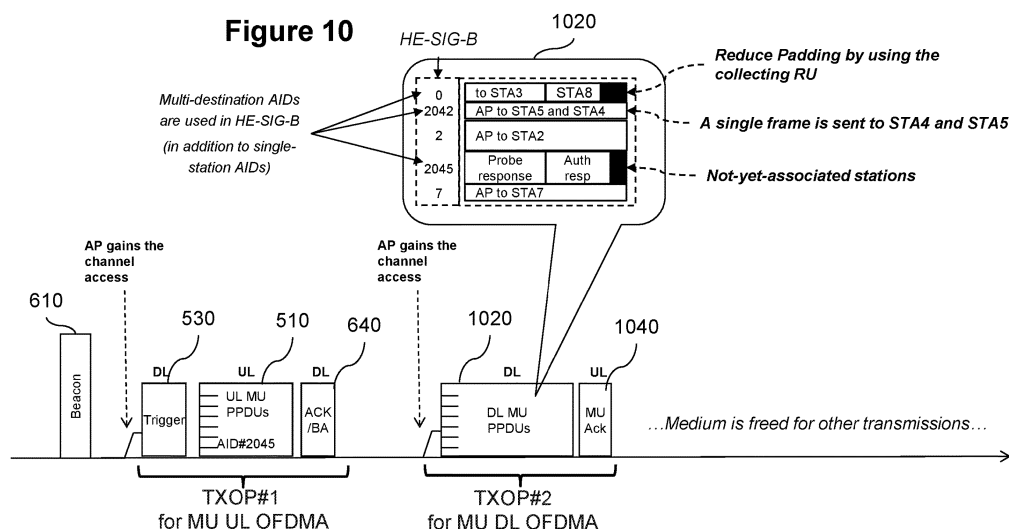
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(54) Title of the Invention: Multi-user resource units in a multi-user downlink transmission of a 802.11AX network
Abstract Title: Multi-user resource units in a multi-user transmission for a wireless communication system

(57) The invention provides resource units (RUs) in a multi-user (MU) transmission between an access point and station wherein a RU is dedicated to a plurality of wireless stations. In a first aspect of the invention a station determines a RU that is dedicated to a plurality of stations from amongst many RUs that form a MU downlink (DL) transmission opportunity (TXOP) for an access point (AP). The station then receives aggregated data frames over the determined RU and retrieves one or more data frames that are addressed to the station from amongst the received aggregated data frames.

Further aspects of the invention provide the registration of stations to an AP, the station being associated with a unique association identifier (AID) which is used by the AP to assign a RU to a station. The station determines a RU that is assigned to an AID that is not associated with a specific station from several RUs forming a MU DL TXOP and receives one or more data frames from the AP on the determined DL RU.

The invention may use OFDMA and may be associated with IEEE standard 802.11ax.



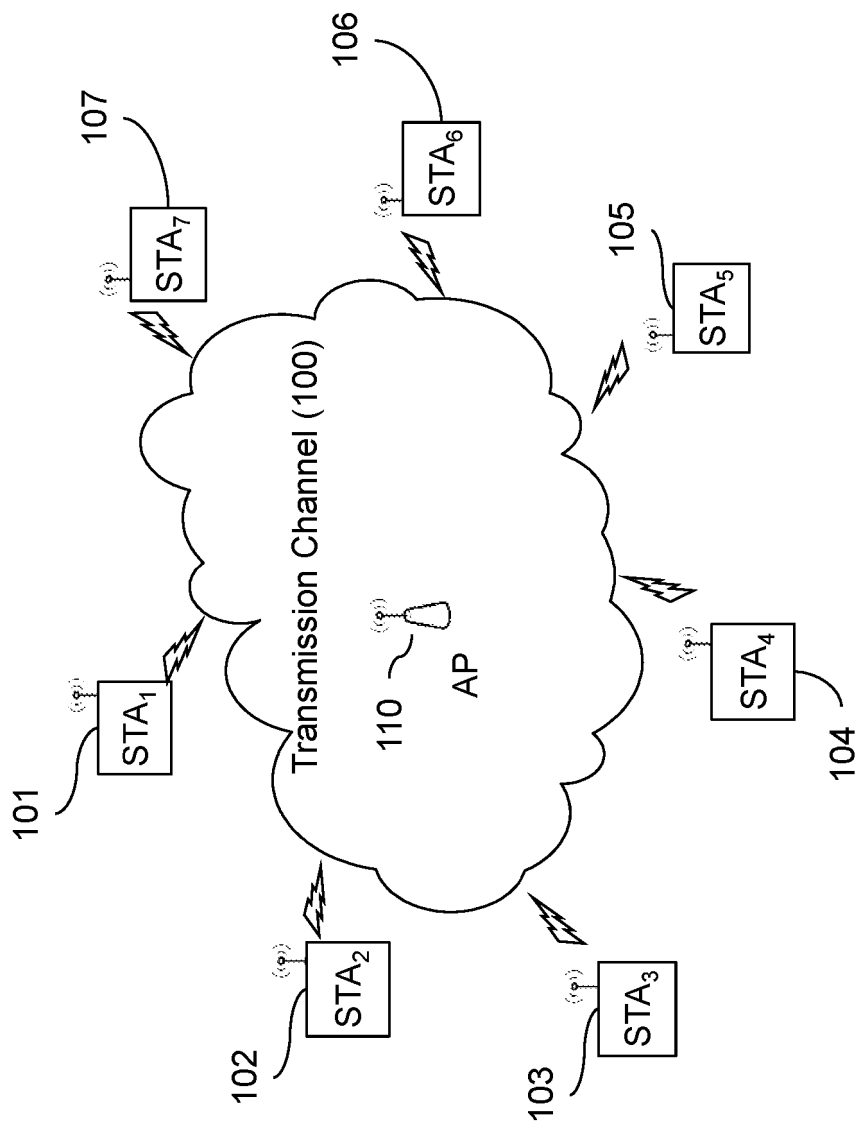


Figure 1

FIGURE 2a : NON_HT PPDU format (legacy)

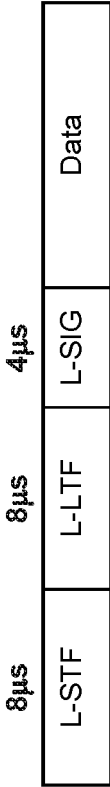


FIGURE 2b : HE SU PPDU format

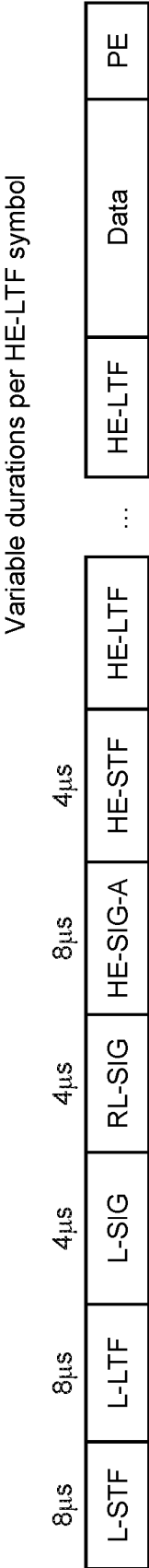


FIGURE 2c : HE MU PPDU format

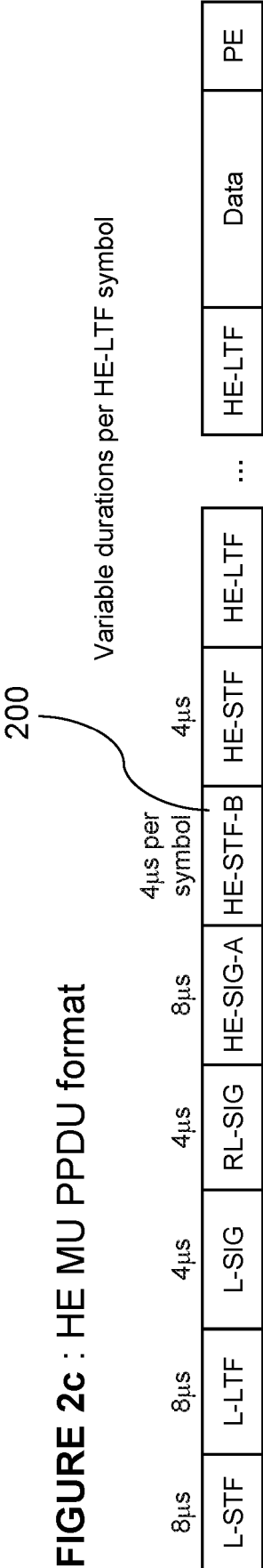
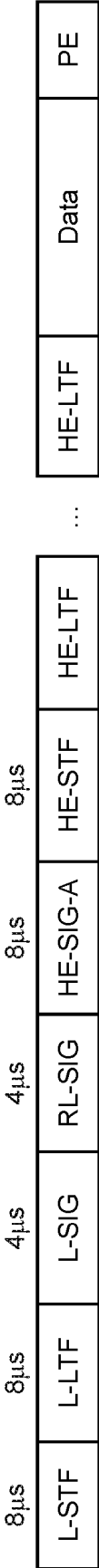
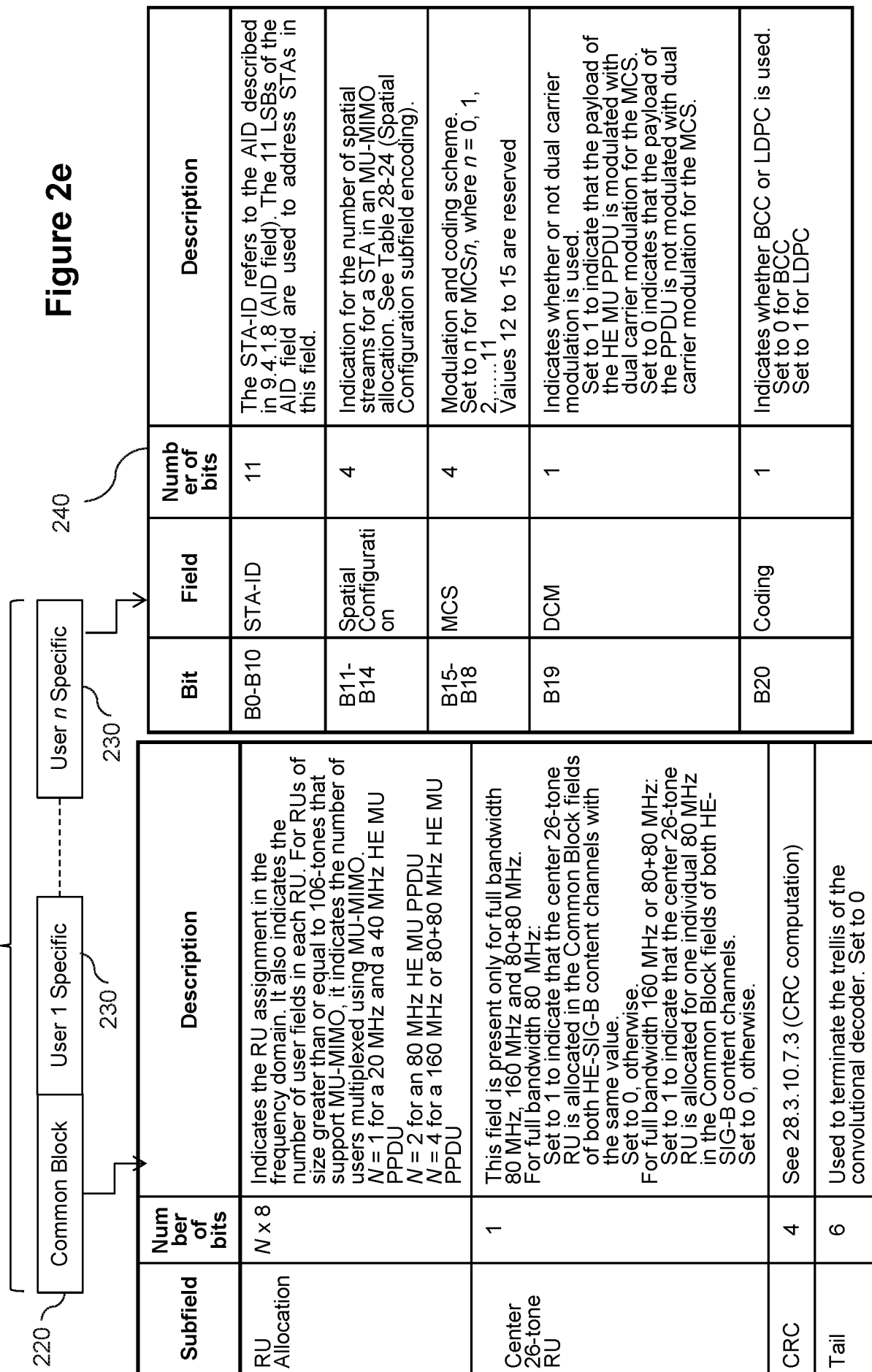


FIGURE 2d : HE trigger-based PPDU



200



8 bits indices (B7 B6 B5 B4 B3 B2 B1 B0)	#1	#2	#3	#4	#5	#6	#7	#8	#9	Number of entries
00000000	26	26	26	26	26	26	26	26	26	1
00000001	26	26	26	26	26	26	26	52	52	1
00000010	26	26	26	26	26	52	52	26	26	1
00000011	26	26	26	26	26	52	52	52	52	1
00000100	26	26	52	52	26	26	26	26	26	1
00000101	26	26	52	52	26	26	26	52	52	1
00000110	26	26	52	52	26	52	52	26	26	1
00000111	26	26	52	52	26	52	52	52	52	1
00001000	52	52	26	26	26	26	26	26	26	1
00001001	52	52	26	26	26	26	26	52	52	1
00001010	52	52	26	26	26	52	52	26	26	1
00001011	52	52	26	26	26	52	52	52	52	1
00001100	52	52	52	52	26	26	26	26	26	1
00001101	52	52	52	52	26	26	26	52	52	1
00001110	52	52	52	52	26	52	52	26	26	1
00001111	52	52	52	52	26	52	52	52	52	1
00010y ₂ y ₁ y ₀	52	52	52	52	-	-	106	106	106	8
00011y ₂ y ₁ y ₀	106			106	-	-	52	52	52	8
00100y ₂ y ₁ y ₀	26	26	26	26	26	26	106	106	106	8
00101y ₂ y ₁ y ₀	26	26	52	52	26	26	106	106	106	8
00110y ₂ y ₁ y ₀	52	52	26	26	26	26	106	106	106	8
00111y ₂ y ₁ y ₀	52	52	52	52	26	26	106	106	106	8

8 bits indices (B7 B6 B5 B4 B3 B2 B1 B0)	#1	#2	#3	#4	#5	#6	#7	#8	#9	Number of entries
01000y ₂ y ₁ y ₀	106			26	26	26	26	26	26	8
01001y ₂ y ₁ y ₀	106			26	26	26	26	52	52	8
01010y ₂ y ₁ y ₀	106			26	26	52	52	26	26	8
01011y ₂ y ₁ y ₀	106			26	26	52	52	52	52	8
0110y ₁ y ₀ z ₁ z ₀	106			-	-	106	106	106	106	16
01110000	52	52	52	-	-	52	52	52	52	1
01110001	242-tone RU empty									1
01110010	484-tone RU with zero HE-SIG-B User Specific field in the corresponding HE-SIG-B Content Channel									1
01110011	996-tone RU with zero HE-SIG-B User Specific field in the corresponding HE-SIG-B Content Channel									1
011101x ₁ x ₀	Reserved									4
011111x ₁ x ₀	Reserved									8
10y ₂ y ₁ y ₀ z ₂ z ₁ z ₀	106			26	26	106	106	106	106	64
11000y ₂ y ₁ y ₀	242									8
11001y ₂ y ₁ y ₀	484									8
11010y ₂ y ₁ y ₀	996									8
11011y ₂ y ₁ y ₀	2x996									8
111x ₄ x ₃ x ₂ x ₁ x ₀	Reserved									32

Figure 2f (contd.)

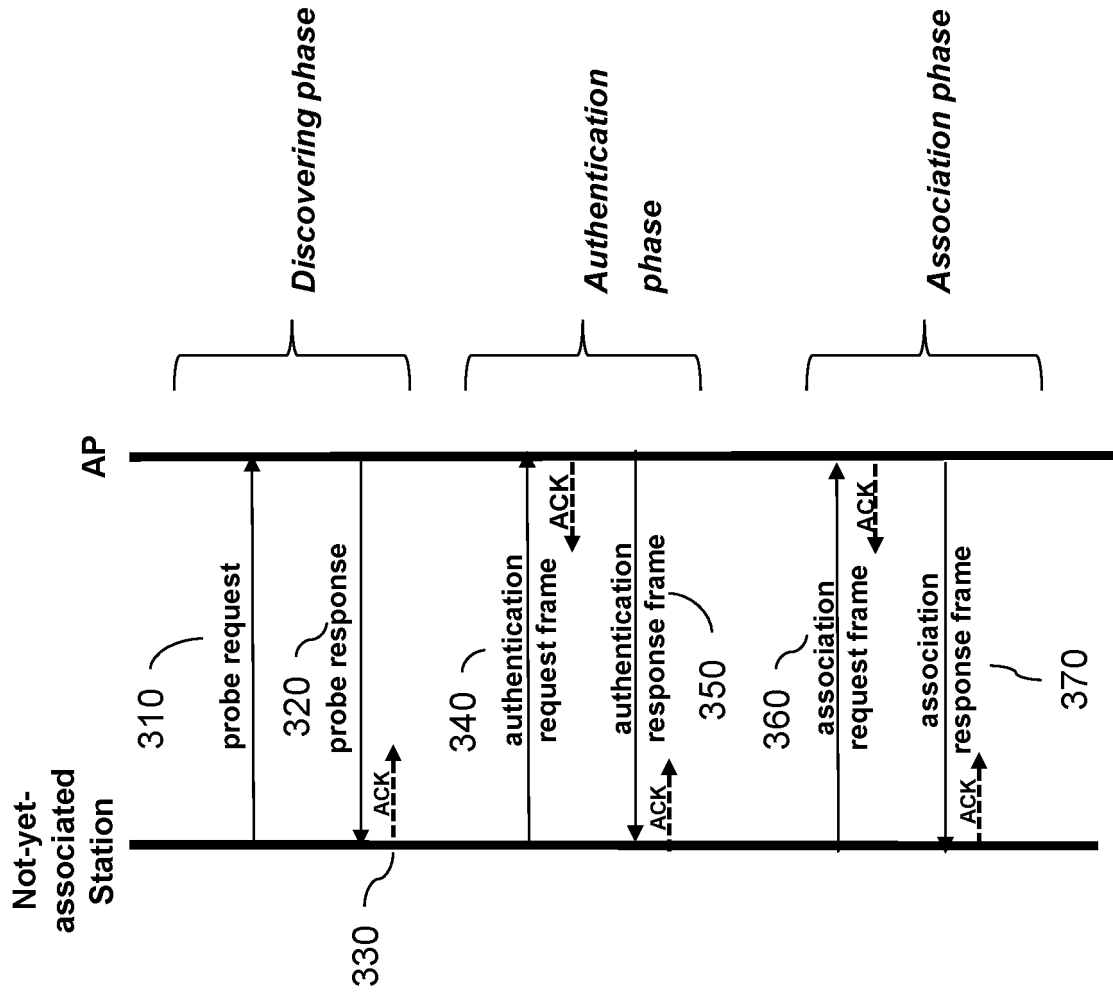


Figure 3

$y_2y_1y_0 = 000-111$ indicates number of STAs multiplexed in the only 106-tone RU or the left 106-tone RU if there are two 106-tone RUs. The binary vector $y_2y_1y_0$ is indexed as $[y[3]y[2]y[1]]$ indicates $2^2 \times y[3] + 2^1 \times y[2] + y[1] + 1$ STAs multiplexed in the RU.

$z_2z_1z_0 = 000-111$ indicates number of STAs multiplexed in the right 106-tone RU if there are two 106-tone RUs. The binary vector $z_2z_1z_0$ is indexed as $[z[3]z[2]z[1]]$ indicates $2^2 \times z[3] + 2^1 \times z[2] + z[1] + 1$ STAs multiplexed in the RU.

Similarly, $y_1y_0 = 00-11$ indicates number of STAs multiplexed in the left 106-tone RU. The binary vector y_1y_0 is indexed as $[y[2]y[1]]$ indicates $2^1 \times y[2] + y[1] + 1$ STAs multiplexed in the RU.

Similarly, $z_1z_0 = 00-11$ indicates the number of STAs multiplexed in the right 106-tone RU. The binary vector z_1z_0 is indexed as $[z[2]z[1]]$ indicates $2^1 \times z[2] + z[1] + 1$ STAs multiplexed in the RU.

#1 to #9 (from left to the right) is ordered in increasing order of the absolute frequency.

$x_1x_0 = 00-11$, $x_4x_3x_2x_1x_0 = 00000-11111$.

'-' means no STA in that RU.

Figure 2f

Figure 4

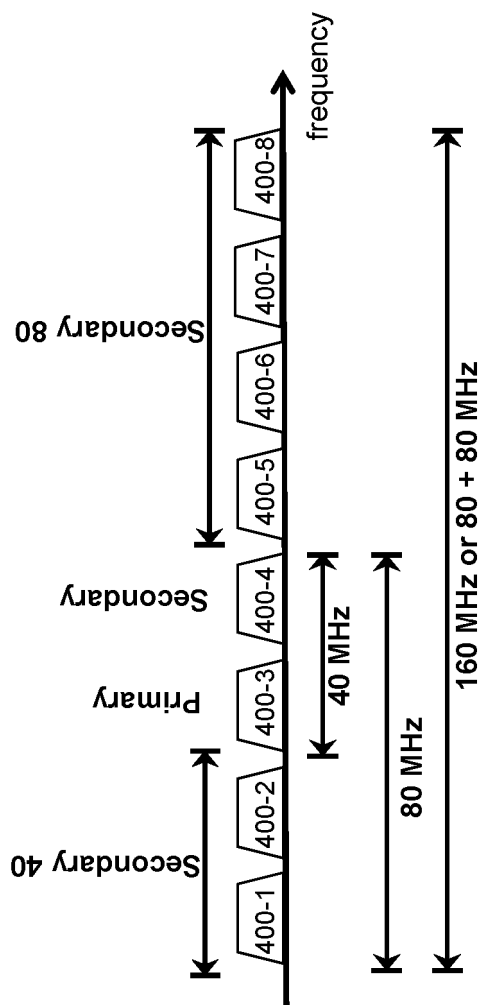
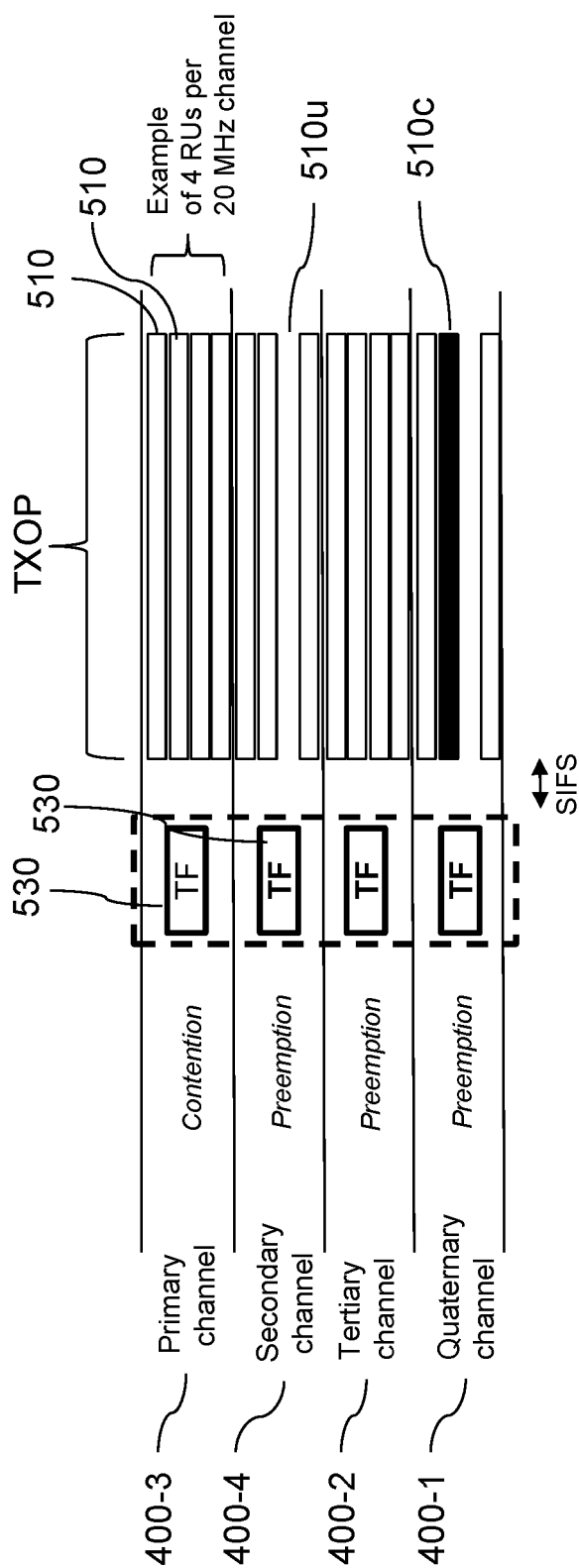


Figure 5



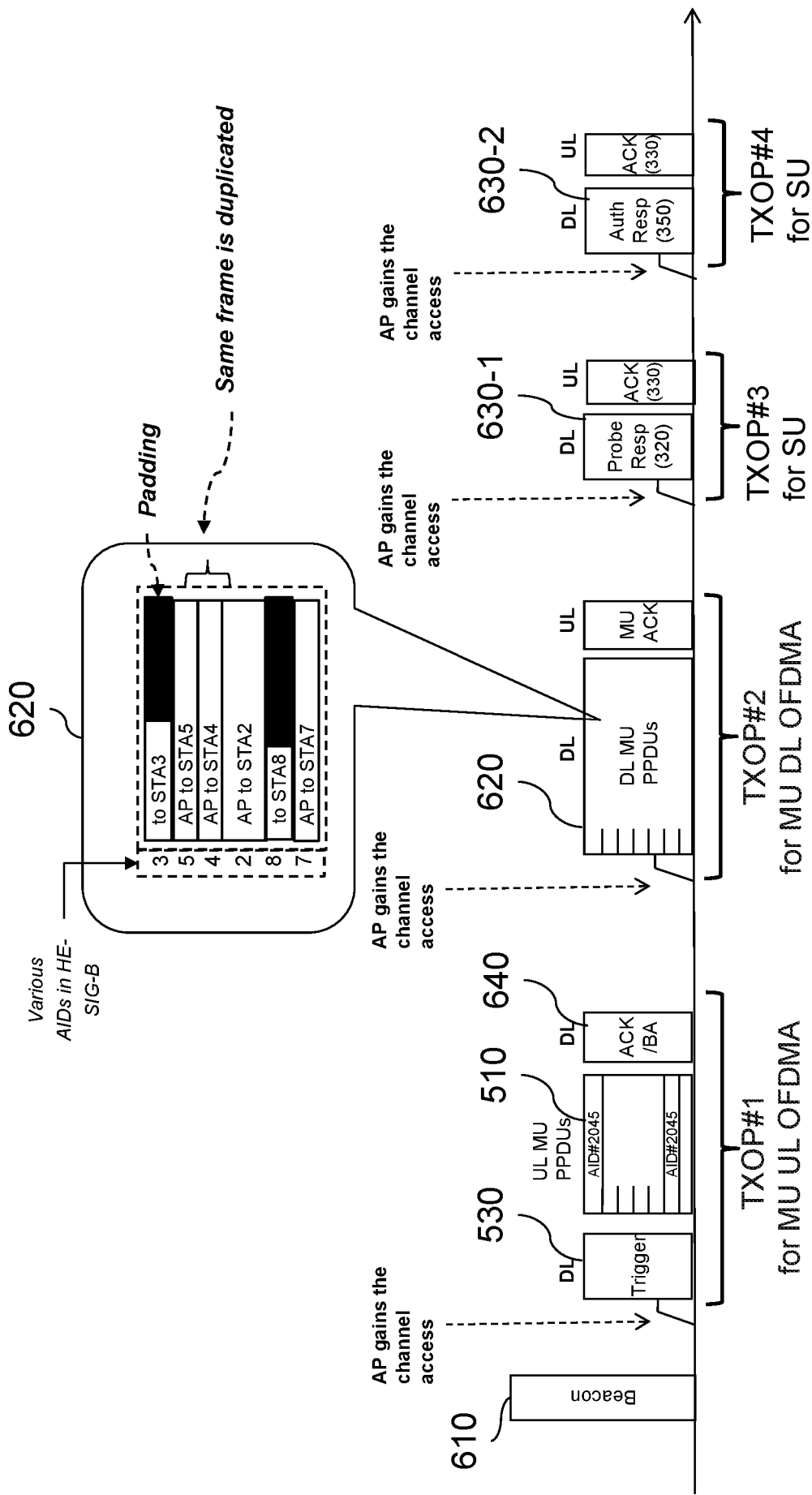


Figure 6

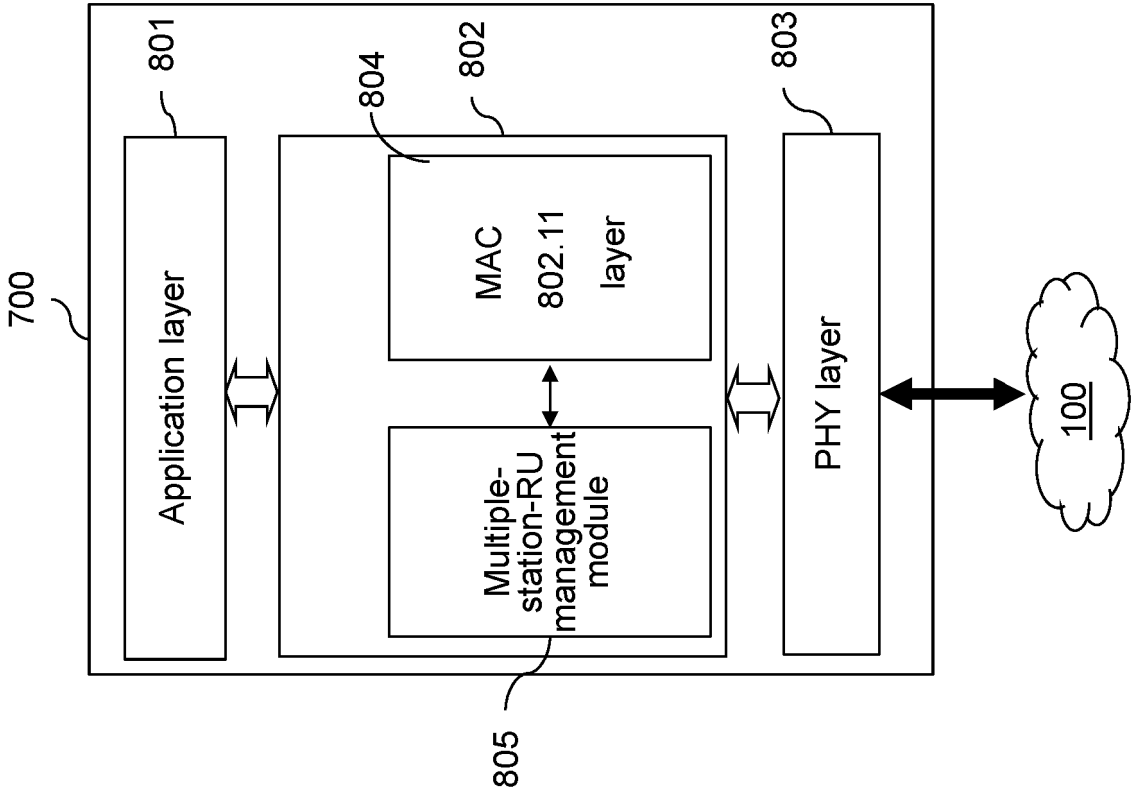


Figure 8

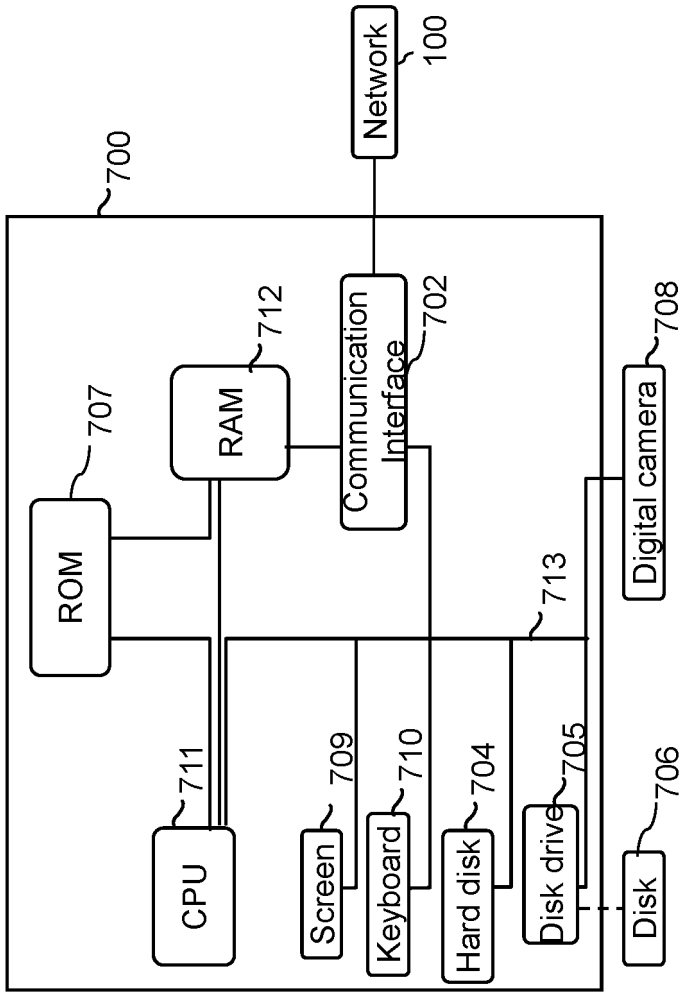


Figure 7

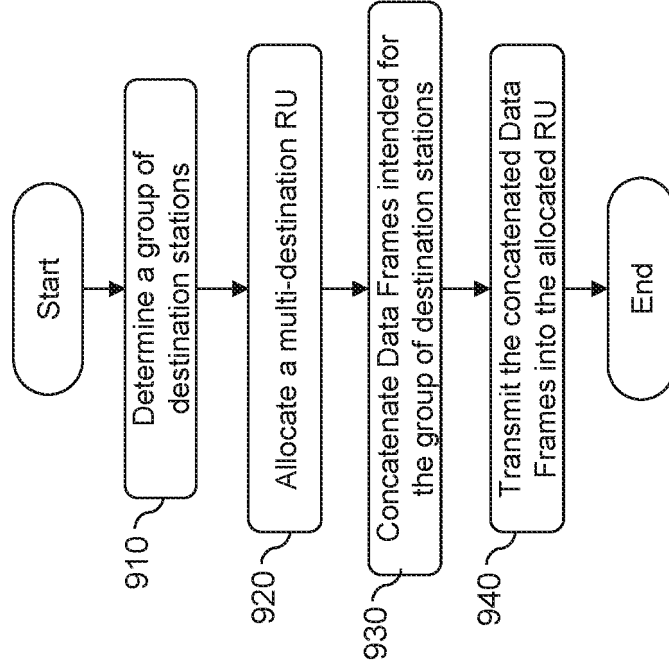


Figure 9a

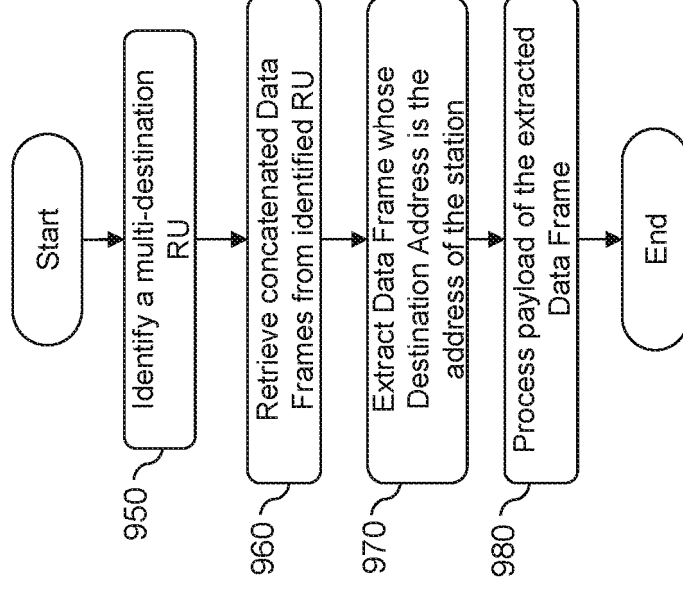


Figure 9b

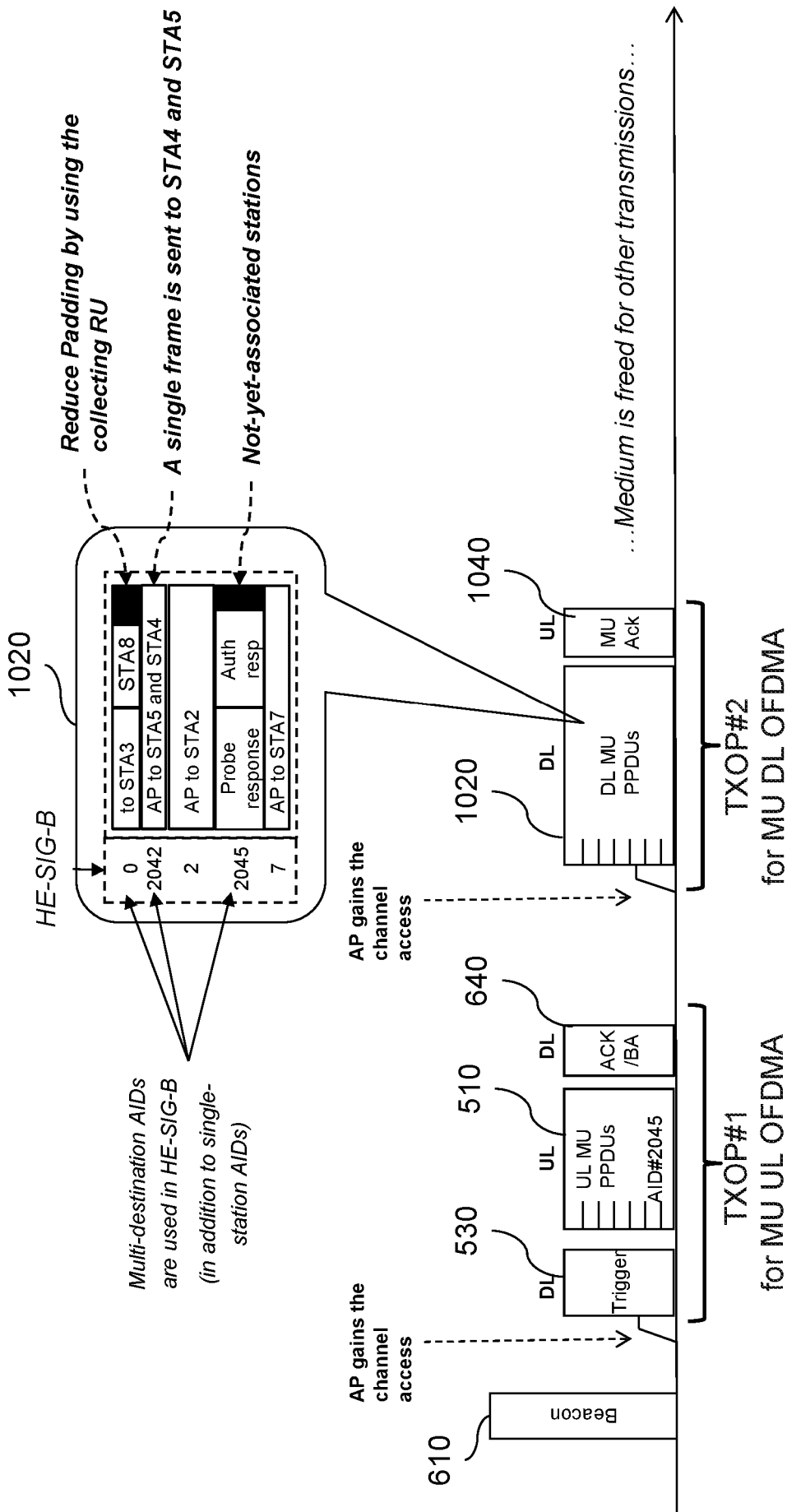


Figure 10

MULTI-USER RESOURCE UNITS IN A MULTI-USER DOWNLINK TRANSMISSION OF A 802.11AX NETWORK

5 FIELD OF THE INVENTION

The present invention relates generally to wireless communication networks comprising an access point (AP) and stations and more specifically to the transmission of data frames within a transmission opportunity made of sub-channels or Resource Units, and corresponding devices.

10 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 Downlink communication from the access point to the stations. One application of the method regards wireless data communication over a wireless communication network using Carrier Sense Multiple Access with Collision Avoidance
15 (CSMA/CA), the network being accessible by a plurality of station devices.

BACKGROUND OF THE INVENTION

The IEEE 802.11 MAC family of standards (a/b/g/n/ac/etc.) defines a way wireless local area networks (WLANs) work at the physical and medium access control (MAC) level.
20 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.

More recently, Institute of Electrical and Electronics Engineers (IEEE) officially
25 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 (or stations) used in dense deployment scenarios.

In this context, multi-user (MU) transmission has been considered to allow multiple simultaneous transmissions to/from different stations (i.e. users) registered to the AP, in both
30 downlink (DL) and uplink (UL) directions from/to the AP, during a transmission opportunity granted to the AP over a 20MHz (or more) communication channel.

In the uplink, multi-user transmissions are used to mitigate the collision probability. This is because multiple non-AP stations are allowed to transmit simultaneously.

To actually perform such multi-user transmission, it has been proposed to split a
35 granted communication channel (or transmission opportunity granted to the AP) into sub-channels, also referred to as resource units (RUs), that are usually shared in the frequency domain between multiple users (non-AP stations/nodes), based for instance on Orthogonal Frequency Division Multiple Access (OFDMA) technique.

Both multi-user Downlink OFDMA and Uplink OFDMA mechanisms offer overhead reduction as key benefit.

To perform multi-user (MU) Downlink OFDMA transmission, the AP sends an MU packet over the whole granted communication channel, meaning that, from an RU point-of-view, the same preamble is transmitted. Next, RU-dependent payload is sent by the AP, meaning the payload varies from one RU to the other, within the whole granted communication channel. The assignment of the RUs to the stations is signalled at the beginning of the MU Downlink frame, by providing an association identifier (AID) of a station for each RU defined in the transmission opportunity.

Such an AID is individually obtained by each station when registering with the AP during an association procedure, that is to say when the station joins the group of stations managed by the AP. During the association procedure, the not-yet-associated station and the AP exchange a series of single user (SU) 802.11 management frames in order to enter into an authenticated and associated state for the station. A result of the association procedure is that an AID is assigned to the station, enabling it to use MU communications (resource units).

An AID is usually formed by the 11 least significant bits of a 12-bit identifier.

One station is thus registered with the AP and has an AID, or is not yet registered with the AP and has no AID until registration is completed.

A group of stations together with the access point is known as a Basic Service Set (BSS). To be noted that the range of available AIDs has to be shared between the several groups of stations (i.e. several BSSs) that could be handled by the same physical access point (though instantiating virtual access points).

To perform multi-user (MU) Uplink OFDMA transmission, the AP sends a control frame, known as Trigger Frame (TF), to the stations prior they can access one RU assigned to them. The assignment of the RUs to the stations is signalled in a similar way as above (for Downlink transmission using AIDs), but in the payload of the TF packet.

As a station is usually provided with a single transceiver, assignment of multiple RUs to one and the same station shall not be allowed in 802.11ax, for both multi-user Downlink and Uplink transmissions.

Thus, at most one RU is assigned to a station, but all the stations will be offered the same RU length. This has several implications.

With respect to the multi-user Uplink OFDMA transmission, the AP does not know how much data each station has to transmit. 802.11ax thus requires that the AP provides, in the Trigger Frame to the stations, an indication on the size of the requested (and granted) transmission opportunity, i.e. how long each station can transmit data in its allocated RU.

With respect to the multi-user Downlink OFDMA transmission, the AP may have different amounts of data to transmit to the stations. The AP thus has to add padding bits to the shortest packets, until the transmission opportunity ends.

Padding should be avoided as it is a waste of bandwidth.

Also, the association procedure introduced above appears to be bandwidth consuming. This is mainly because the SU management frame are transmitted at low bit rate (usually the lowest supported data rate) over the 20MHz channel, in order for legacy stations (i.e. not implementing 802.11ax) to be able to understand the common 802.11 preamble. This is also because each SU management frame requires a specific access to the medium by the station, and thus requires for the station to wait until being granted a new medium access. As the number of BSSs increases in the same area and/or as the number of stations within a BSS substantially increases, more channel bandwidth is lost due to such SU signaling, and the cost to access the medium by the stations increases.

Recently, the 802.11ax task group has proposed a mechanism for the AP to reserve one or more RUs of a multi-user Uplink OFDMA transmission for not-yet-associated stations (which are 802.11ax compliant). This is for these stations to speed up their registration to the AP, by transmitting request management frames over such reserved RUs (in MU Uplink OFDMA mode). The proposed mechanism relies on the use of a predefined AID value equal to 2045 to indicate the random RUs the not-yet-associated stations can access through contention.

Even with this new mechanism, the response management frames from the AP are performed using low bit rate SU signaling. This is because, by failing to have an own AID, these not-yet-associated stations cannot be assigned with RUs in a MU Downlink transmission. It remains that channel bandwidth is still wasted.

In addition, 802.11 does not provide mechanisms for multicast traffic, while the AP may receive multicast frames from an upper OSI layer, e.g. the link layer implementing Ethernet multicast. In that case, the AP has to generate a plurality of data frames including payload of the received multicast frame, to be each individually addressed to a respective one of the addressee stations (of the multicast frame). Next, each data frame is transmitted in a dedicated RU of the multi-user Downlink OFDMA transmission, thereby resulting in duplicating several times the same payload data over several RUs. Again, channel bandwidth is wasted.

The current operating mode of the 802.11ax multi-user feature is thus not fully satisfactory, for at least the above downsides regarding the padding bits, the SU signaling for registration and the frame duplication for multicast traffic.

SUMMARY OF INVENTION

It is a broad objective of the present invention to improve this situation, i.e. to overcome some or all of the foregoing limitations. In particular, the present invention seeks to provide a more efficient usage of the MU Downlink transmission from the AP.

In particular, the Multi-User Downlink communication protocol is enhanced to support a multiplicity of addressee stations for the same Downlink RU, including those stations which have not yet received an AID (i.e. not yet registered or associated with the AP).

In this context, the present invention proposes enhanced wireless communication methods in a wireless network comprising an access point and stations.

In embodiments, the method comprises the following steps, at one of the stations:

5 determining a resource unit dedicated to a plurality of stations, from amongst a plurality of resource units forming a multi-user downlink transmission opportunity granted to the access point for downlink communication to the stations;

receiving aggregated data frames over the determined resource unit; and

retrieving one or more data frames addressed to the station, from amongst the received aggregated data frames.

10 In other embodiments, any station registering with the access point being associated with a unique association identifier used by the access point to assign, to the station, a resource unit in a transmission opportunity granted to the access point, and the method comprises the following steps, at one of the stations:

15 determining a resource unit assigned to an association identifier not associated with a specific station, from a plurality of resource units forming a multi-user downlink transmission opportunity granted to the access point for downlink communication to the stations; and

receiving one or more data frame from the access point on the determined downlink resource unit.

20 From the AP perspective, enhanced wireless communication methods in a wireless network comprising an access point and stations are also proposed.

In embodiments, the method comprises the following steps, at the access point:

aggregating data frames addressed to two or more stations; and

25 transmitting the aggregated data frames over a resource unit dedicated to a plurality of stations, from amongst a plurality of resource units forming a multi-user downlink transmission opportunity granted to the access point for downlink communication to the stations.

30 In other embodiments, any station registering with the access point being associated with a unique association identifier used by the access point to assign, to the station, a resource unit in a transmission opportunity granted to the access point, and the method comprises the following steps, at the access point:

35 building a plurality of resource units forming a multi-user downlink transmission opportunity granted to the access point for downlink communication to the stations, the plurality of resource units comprising a resource unit assigned to an association identifier not associated with a specific station; and

transmitting one or more data frames to a station on the resource unit assigned to an association identifier not associated with a specific station.

By combining data frames to be addressed to several stations within the same dedicated RU, embodiments of the invention make it possible for the AP to efficiently target a

large number of stations, thereby using more efficiently each RU (and thus reducing padding bits), avoiding duplicating the same payload over several RUs (in case of multicast) and/or efficiently (i.e. at a higher bit rate) providing response management frames to the not-yet-associated stations.

5 In the other embodiments, by using AID not associated with stations during MU Downlink transmissions, the invention offers the AP with the opportunity to address one or more stations deprived of AID. Such stations may thus easily identify, in a Downlink transmission, which RU to listen to.

MU Downlink transmission is thus significantly improved compared to known
10 802.11ax current requirements.

Also, there is provided a wireless communication device forming station in a wireless network comprising an access point and stations.

In embodiments, the device forming station comprising at least one microprocessor configured for carrying out the steps of:

15 determining a resource unit dedicated to a plurality of stations, from amongst a plurality of resource units forming a multi-user downlink transmission opportunity granted to the access point for downlink communication to the stations;

receiving aggregated data frames over the determined resource unit; and

retrieving one or more data frames addressed to the station, from amongst the
20 received aggregated data frames.

In other embodiments, any station registering with the access point being associated with a unique association identifier used by the access point to assign, to the station, a resource unit in a transmission opportunity granted to the access point, and the device forming station comprises at least one microprocessor configured for carrying out the steps of:

25 determining a resource unit assigned to an association identifier not associated with a specific station, from a plurality of resource units forming a multi-user downlink transmission opportunity granted to the access point for downlink communication to the stations; and

receiving one or more data frame from the access point on the determined
30 downlink resource unit.

Also, there is provided a wireless communication device forming access point in a wireless network comprising an access point and stations.

In embodiments, the device forming access point comprising at least one microprocessor configured for carrying out the steps of:

35 aggregating data frames addressed to two or more stations; and

transmitting the aggregated data frames over a resource unit dedicated to a plurality of stations, from amongst a plurality of resource units forming a multi-user downlink transmission opportunity granted to the access point for downlink communication to the stations.

In other embodiments, any station registering with the access point being associated with a unique association identifier used by the access point to assign, to the station, a resource unit in a transmission opportunity granted to the access point, and the device forming access point comprises at least one microprocessor configured for carrying out the

5 steps of:

building a plurality of resource units forming a multi-user downlink transmission opportunity granted to the access point for downlink communication to the stations, the plurality of resource units comprising a resource unit assigned to an association identifier not associated with a specific station; and

10 transmitting one or more data frames to a station on the resource unit assigned to an association identifier not associated with a specific station.

Optional features of these embodiments are defined in the appended claims with reference to methods. Of course, same features can be transposed into system features dedicated to any device according to the embodiments of the invention.

15 In embodiments related to the station determining a resource unit assigned to an association identifier not associated with a specific station, the method may further comprise, at the station:

receiving aggregated data frames over the determined resource unit; and
retrieving one or more data frames addressed to the station, from amongst the

20 received aggregated data frames.

Correspondingly, at the access point, the method may further comprise:
aggregating data frames to be addressed to two or more stations; and
transmitting the aggregated data frames over the resource unit assigned to an association identifier not associated with a specific station.

25 In embodiments, any station registering with the access point is associated with a unique association identifier used by the access point to assign, to the station, a resource unit in a transmission opportunity granted to the access point, and the resource unit dedicated to a plurality of stations is assigned in the downlink transmission opportunity to a predefined association identifier not associated with a specific station. This may be seen as a "group AID"

30 for a group of stations. All 802.11ax compliant stations may thus be aware of such predefined AID or AIDs, in order to scrutinize the relevant RU.

In some embodiments, the access point may set, in each data frame to be aggregated, a MAC address field to a MAC address of the addressee station. This is to allow the addressee stations to efficiently retrieve their own data frames. Indeed, from the station

35 perspective, retrieving one or more data frames addressed to the station may thus include comparing a MAC address of each aggregated data frame with a MAC address of the station.

To avoid too much processing at the access point, the station may not acknowledge receipt of the retrieved data frames, to the access point. Thus all the data frames in the Downlink RU are not acknowledged.

In a variant, the station may send an acknowledgment of the retrieved data frames only if the retrieved data frames include the last received aggregated data frame. It means that only the last data frame is explicitly acknowledged by its corresponding receiving station, and the other data frames of the Downlink RU for the group of stations are thus implicitly
 5 acknowledged as soon as the acknowledgment for the last one is correctly received.

As introduced above, one application of the present invention regards the management frames for the not-yet-associated (registered) stations to efficiently register with the access point. In this context, the station may, prior to determining a resource unit, send a management frame to the access point within a procedure of associating (i.e. registering) the
 10 station with the access point. In such case, determining a resource unit include determining a resource unit assigned to stations not yet associated with the access point, to retrieve a response from the access point to the sent management frame. In other words, a resource unit in the Downlink OFDMA transmission is reserved for the not-yet-associated stations, from which RU they may obtain the responses to their request management frames.

15 This approach avoids using SU signalling even for the response management frames. Network bandwidth is thus saved.

From AP's perspective, it may mean that the access point, prior to the step of transmitting data frames, receives at least one management frame from a station willing to associate (i.e. register) with the access point, and the transmitted data frames include a
 20 response to the received management frame and are transmitted over a resource unit assigned to stations not yet associated with the access point.

To provide an enhanced association procedure, the management frame is sent in a prior resource unit forming part of an uplink transmission opportunity granted to the access point for uplink communication from the stations, the prior resource unit being assigned to stations
 25 not yet associated with the access point. Thus, both request and response management frames can be sent in (high bit rate) MU OFDMA RUs, thereby reducing medium occupancy.

In some embodiments, the determined resource unit and the prior resource unit are assigned in the downlink and uplink transmission opportunities respectively, to the same prefixed association identifier not associated with a specific station, for instance AID=2045 or an
 30 association identifier associated with a basic service set (provided by the AP), for instance equal to the basic service set identifier of the basic service set. This makes the management at the stations and the access point easier.

To further improve the association procedure, the station may send an acknowledgment of the retrieved data frames, in a next resource unit forming part of a next
 35 uplink transmission opportunity granted to the access point for uplink communication from the stations, the next resource unit being assigned to stations not yet associated with the access point. This is an efficient way to provide, at low cost, an opportunity to each not-yet-associated station willing to register, to acknowledge receipt of response management frames (i.e. without using SU signalling).

Another application of the present invention regards the management of multicast traffic or any residual traffic (i.e. small amounts of data that would require padding bits given the RU size).

In the case of multicast traffic, the access point receives a multicast frame (e.g. from an upper OSI layer) to be addressed to a plurality of addressee stations. Next, responsive to the multicast frame reception, the access point generates a plurality of data frames including payload of the multicast frame, to be each individually addressed to a respective one of the addressee stations. The aggregated data frames to be transmitted over the resource unit dedicated to a plurality of stations thus include the generated data frames including payload of the multicast frame.

For instance, the resource unit dedicated to a plurality of stations to transmit the aggregated data frames including the payload of the multicast frame may be assigned in the downlink transmission opportunity to a prefixed association identifier not associated with a specific station equal to 2042.

In the case of residual traffic, the access point may determine small data frames to be transmitted to stations, given a size of the downlink transmission opportunity (possibly the size of the RUs) and a size threshold. Thus, the determined small data frames are aggregated and transmitted over the resource unit dedicated to a plurality of stations, referred to as collecting resource unit. For instance, the collecting resource unit is signalled in the downlink transmission opportunity using a prefixed association identifier equal not associated with a specific station to 0.

From the station perspective, both multicast and residual traffic can be handled in the same way. For instance, the station may first scan through resource units assigned to individual stations to verify whether a resource unit of the plurality is individually assigned to the station or not, and in case of negative verification only, determining a resource unit dedicated to a plurality of stations from the not-yet scanned resource units of the plurality. In particular, determining a resource unit dedicated to a plurality of stations from the not-yet scanned resource units may comprise first scanning through resource units assigned to lists of stations to verify whether the station belongs to a list associated with one of the scanned resource units. The list may for instance correspond to a specific AID used as a group AID, each station being able to determine whether or not it belongs to such group (for instance through bit masking or with reference to group AID provided by the AP upon registration).

Thus, in case of positive verification, the determined resource unit (to retrieve the data frames) is the one assigned to a list that includes the station.

Also, in case of negative verification only, the determined resource unit is a collecting resource unit used to convey data frames for any station not assigned, individually or through a list, to another resource unit forming the downlink transmission opportunity.

These various approaches avoid duplicating the same data over several RUs and/or reduce the amount of padding data to be added in the RUs. Consequently, medium use is made more efficient.

To ensure efficient processing by the stations, embodiments provide that the
5 downlink transmission opportunity includes an ordered signalling of assignments of resource units of the plurality to one or more stations, the ordered signalling first defining each assignment of a resource unit to an individual station, next defining each assignment of a resource unit to a group of stations, then defining an assignment of the collecting resource unit to any station not yet associated with a resource unit. Indeed, a station will thus first determine
10 individual RUs, before (in case of negative verification) considering whether or not a group RU has been used. Thus, only if no RU has been identified for the station, the latter can scrutinize the collector RU (dedicated to any station) to possibly retrieve some data addressed to it.

Thanks to this approach, a station may advantageously disregard any further RU analysis in the same Downlink transmission opportunity, once it has found one RU (individual or
15 group) addressed to it.

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
20 that are analogous to those set out above and below in relation to the methods and devices.

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
25 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
30 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;

Figures 2a to 2f present various formats of 802.11 frames according to the 802.11ax standard;

Figure 3 illustrates an exemplary sequence of management frames allowing a not-yet-associated station to discover and register with a given Access Point;

Figure 4 illustrates 802.11ac channel allocation that support channel bandwidth of 20 MHz, 40 MHz, 80 MHz or 160 MHz as known in the art;

Figure 5 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 6 illustrates, through an exemplary situation of data transmission in a WLAN, drawbacks of the current version of 802.11ax;

Figure 7 shows a schematic representation a communication device in accordance with embodiments of the present invention;

Figure 8 shows a schematic representation of a wireless communication device in accordance with embodiments of the present invention;

Figure 9a illustrates, using a flowchart, embodiments of the invention implemented at a physical access point when preparing and performing a MU Downlink transmission;

Figure 9b illustrates, using a flowchart, embodiments of the invention implemented at a non-AP station to handle RUs dedicated to groups of stations in MU Downlink transmissions from the AP; and

Figure 10 illustrates the impact of the present invention on the exemplary situation of **Figure 6** described above.

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.

Carrier sensing in CSMA/CA is performed by both physical and virtual mechanisms. Virtual carrier sensing is achieved by transmitting control frames to reserve the medium prior to transmission of data frames.

Next, a source or transmitting station, including the AP, first attempts through the physical mechanism, to sense a medium that has been idle for at least one DIFS (standing for DCF InterFrame Spacing) time period, before transmitting data frames.

However, if it is sensed that the shared radio medium is busy during the DIFS period, the source station continues to wait until the radio medium becomes idle.

To access the medium, the station starts a countdown backoff counter designed to expire after a number of timeslots, chosen randomly in a contention window range $[0, CW]$, CW (integer) being also referred to as the Contention Window size and defining the upper boundary of the backoff selection interval (contention window range). This backoff mechanism or procedure is the basis of the collision avoidance mechanism that defers the transmission time for a random interval, thus reducing the probability of collisions on the shared channel. After the backoff time period, the source station may send data or control frames if the medium is idle.

One problem of wireless data communications is that it is not possible for the source station to listen while sending, thus preventing the source station from detecting data corruption due to channel fading or interference or collision phenomena. A source station remains unaware of the corruption of the data frames sent and continues to transmit the frames unnecessarily, thus wasting access time.

The Collision Avoidance mechanism of CSMA/CA thus provides positive acknowledgement (ACK) of the sent data frames by the receiving station if the frames are received with success, to notify the source station that no corruption of the sent data frames occurred.

The ACK is transmitted at the end of reception of the data frame, immediately after a period of time called Short InterFrame Space (SIFS).

If the source station does not receive the ACK within a specified ACK timeout or detects the transmission of a different frame on the channel, it may infer data frame loss. In that case, it generally reschedules the frame transmission according to the above-mentioned backoff procedure.

While the communication system of **Figure 1** shows a single physical access point 110, the AP 110 may support multiple BSSs (also called set of “virtual APs”) and be configured to manage one or more WLANs (or BSSs), i.e. one or more groups of stations. Each BSS has to be uniquely identified by a specific basic service set identification, BSSID.

To achieve this configuration, the physical AP 110 may implement two (or more) virtual APs to manage two (or more) WLANs, for instance: virtual AP 1 VAP-1 (not shown)

having MAC address MAC1 as specific BSSID to manage a first WLAN (BSS) with “guest” as SSID, and virtual AP 2 VAP-2 (not shown) having MAC address MAC2 as specific BSSID to manage a second WLAN (BSS) with “Employee” as SSID.

Some stations can register with VAP-1 and thus join the first WLAN “guest”, while
 5 other stations can simultaneously register with VAP-2 and thus join the second WLAN “Employee”.

The security for each WLAN can be made different, i.e. WEP and WPA.

An AP device that supports multiple BSSIDs includes two types of virtual APs. The first one is referred to as “transmitted AP” or “representative AP”. Its BSSID is referred to as
 10 transmitted BSSID. It takes the primary role to transmit Multiple BSSID elements in beacon and probe response frames. For a given physical AP, only one virtual AP is designated as transmitted AP.

The second type of virtual APs is referred to as “non-representative AP” or “non-transmitted AP”. Its BSSID is referred to as non-transmitted BSSID. The non-representative
 15 APs correspond to other virtual APs which shall not broadcast beacon frames with Multiple BSSID elements. However they may broadcast beacon frames specific to its own BSS, i.e.; without Multiple BSSID elements, in order to associate legacy STAs (stations not implementing IEEE 802.11v) with itself.

The same physical device can join two WLANs simultaneously only if it has two
 20 separate WLAN interfaces (e.g. wifi network cards). In that case, the device is considered as two stations in the network, each station being registered with only one WLAN at a time.

For the stations to be aware of available WLANs (or BSSs) and of the information defining them (for instance corresponding SSID or SSIDs, corresponding specific BSSID or BSSIDs, communication mode including Infrastructure or Ad-Hoc, protection security schemes
 25 used including Open, WEP, WPA-PSK or 802.1X, support transmission rates used, channel in operation, and any optional Information Elements), the AP sends some control or management frames, including beacon frames and probe response frames which have substantially the same content.

A probe response frame is emitted by the AP to a specific station in response to a
 30 probe request frame broadcast by the station. This takes place in an active discovery procedure where the station successively scans the 20MHz channels and broadcast probe request frames therein. In the active discovery procedure, the station has to periodically remind its effective presence by sending new probe request frames.

On the other hand, a passive discovery procedure has been implemented where
 35 the AP voluntarily and periodically (e.g. each 100 ms) broadcasts a beacon frame to declare the WLAN to the stations.

Both beacon frames and probe response frames are used in any version of 802.11, meaning that they are sent at lowest bit rate using a non-HT (High Throughput) PPDU (PLCP Protocol Data Unit) format as shown in **Figure 2a**.

This format is simple as it contains a preamble made of three fields that can be understood by any station according to any version of 802.11: L-STF (Legacy Short Training Field), L-LTF (Legacy Long Training Field) and L-SIG (Legacy Signal Field) fields; followed by a Data field containing the payload data, here the information defining the WLAN to declare.

5 The repetition of the probe request/response frames or of the beacon frames preempts a non-negligible part of network bandwidth. This part substantially increases with multiple WLANs that must share the same communication channels, and also with multiple physical APs (possibly some implementing multiple BSSs), since multiple beacons are thus broadcast (one for each active BSS).

10 As a consequence, the stations have to process beacon frames more frequently and channel occupation due to management frames is increased. Increasing the beacon interval (to be more than 100ms) so that the beacon frame of each BSS is sent less frequently and the station processing and channel occupation are reduced does not seem fully relevant. This is because the WLANs are less visible/detectable by the stations: some stations may not
15 detect the beacon frame of a given BSS when scanning, and thus conclude a particular BSS (through its SSID) is not available; also stations may decide to emit probe request frames to find their networks, in an active manner, which thus results in having probe response frames broadcast by each neighborhood APs.

20 The discovery procedure (using beacon frames or probe response frames) may be the initial part of a more general association procedure during which a station registers with an AP to join a corresponding WLAN.

Figure 3 illustrates an exemplary sequence of management frames allowing a not-yet-associated station to discover and register with a given Access Point. It comprises three phases: WLAN discovery, authentication and association, at the end of which the station enters
25 into an authenticated and associated state with the AP. Note that the station may be currently associated with a first AP (i.e. belonging to a first WLAN) and willing to join a second WLAN.

 802.11 networks make use of a number of options for the first phase of 802.11 probing or discovering. For instance, for an enterprise deployment, the search for a specific network may involve sending a probe request frame out on multiple channels that specifies the
30 network name (SSID) and bit rates.

 More generally, prior to association with the AP, the stations gather information about the APs by scanning the channels one by one either through passive scanning (passive discovery procedure introduced above) or active scanning (active discovery procedure introduced above).

35 In the passive scanning mode, the station scans through successively each 20MHz channel and waits to listen for beacon frames (declaring SSID) on the scanned channel, regardless of whether the stations has already connected to a specific SSID before or not.

 In the active scanning mode, the stations send out probe request frames 310 on each wireless 20MHz channel. The probe request frames may contain the SSID of a specific

WLAN that the station is looking for or the probe request frames may not contain a specific SSID meaning the station is looking for “any” SSID in the vicinity of the station.

In response to receiving a probe request frame, the AP checks whether the station has at least one common supported data rate or not. If there is a compatible data rate, the AP responds with a probe response frame 320, the content of which is similar to a beacon frame: advertising of the SSID (wireless network name), of supported data rates, of encryption types if required, and of other 802.11 capabilities of the AP.

An acknowledgment frame 330 may be sent by the station, in response to receiving the probe response frame 320.

It is also common for a station that is already associated with an AP to send probe request frames regularly onto other wireless channels to maintain an updated list of available WLANs with best signal strengths. Thanks to this list, when the station can no longer maintain a strong connection with the AP, it can roam to another AP with a better signal strength using the second and third phases of the association procedure.

The second phase is the 802.11 authentication once a WLAN to join has been chosen by the station. In particular, the station chooses a compatible WLAN from the probe response frames it receives.

802.11 was originally developed with two authentication mechanisms: the first authentication mechanism, called “open authentication”, is fundamentally a NULL authentication where the station says “authenticate me” and the AP responds with “yes”. This is the mechanism used in almost all 802.11 deployments; the second authentication mechanism, namely the WEP/WPA/WPA2, is a shared key mechanism that is widely used in home networks or small Wi-Fi deployments and provides security.

During the 802.11 authentication phase, the station sends a low-level 802.11 authentication request frame 340 to the selected AP setting, for instance, the authentication to open and the sequence to 0x0001. The AP receives the authentication request frame 340 and responds to the station with an authentication response frame 350 set to open indicating a sequence of 0x0002.

Note that some 802.11 capabilities allow a station to low-level authenticate to multiple APs without being associated with them (i.e. without belonging to corresponding WLANs). This speeds up the whole association procedure when the station moves between APs. Indeed, while a station can be 802.11 authenticated to multiple APs, it can only be actively associated and transferring data through a single AP at a time.

Next, the station has to perform actual association with the AP from the low level authentication step. This is the next phase of actual 802.11 association by which the station actually joins the WLAN cell. This stage finalizes the security and bit rate options and establishes the data link between the station and the AP. The purpose of this final exchange is for the station to obtain an Association Identifier (AID) to be used to access the medium and send data within the joined WLAN.

Note that the station may have joined a first network and may roam from one AP to another within the physical network. In that case, the association is called a re-association.

Once the station determines which AP (i.e. WLAN) it would like to be associated with, the station sends an association request frame 360 to the selected AP. The association request frame contains chosen encryption types if required and other compatible 802.11 capabilities.

If the elements in the association request frame match the capabilities of the AP, the AP creates an Association ID (AID) for the station and responds with an association response frame 370 with a success message granting network access to the station.

Now the station is successfully associated with the AP, data transfer can begin in the chosen WLAN using the physical medium.

Note that when an AP receives a data frame from a station that is authenticated but not yet associated, the AP responds with a disassociation frame placing the station into an authenticated but unassociated state. It results that the station must re-associate itself with the AP to join the corresponding WLAN.

The probe response frame 320, authentication request/response frames 340 and 350 and association request/response frames 360 and 370 are unicast management frames emitted in an 802.11 legacy format, known as a single user (SU) format. This is a format used for point-to-point communication (here between the AP and the station). Each of these unicast management frames is acknowledged by an ACK frame 330.

As indicated above, all the management frames (310, 320, 340, 350, 360, 370) and the ACK frames (330) use the lowest common rate supported by both the station and the AP (e.g. 24mbps or less).

To meet the ever-increasing demand for faster wireless networks to support bandwidth-intensive applications, 802.11ac and later versions (802.11ax for instance) implement larger bandwidth transmission through multi-channel operations. **Figure 4** illustrates an 802.11ac channel allocation that supports composite channel bandwidth of 20 MHz, 40 MHz, 80 MHz or 160 MHz.

IEEE 802.11ac introduced support of a restricted number of predefined subsets of 20MHz channels to form the sole predefined composite channel configurations that are available for reservation by any 802.11ac (or later) station 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 channel bandwidths, compared to only 20 MHz and 40 MHz supported by 802.11n. Indeed, the 20MHz 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 40MHz, 80MHz or 160MHz 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. However 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 station (including the AP) is granted a transmission opportunity (TxOP) through the enhanced distributed channel access (EDCA) mechanism on the “primary channel” (400-3). Indeed, for each composite channel having a bandwidth, 802.11ac designates one channel as “primary” meaning that it is used for contending for access to the composite channel. The primary 20MHz channel is common to all stations (STAs) belonging to the same BSS, i.e. managed by or registered with the same local Access Point (AP).

However, to make sure that no other legacy station (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 or trigger frame described below) reserving the composite channel are duplicated over each 20MHz channel of such composite channel.

Transmissions in such composite channels is made from one station to the other (including the AP) using HE single user (SU) PPDU, the format of which is shown in **Figure 2b**. It comprises, in addition to the conventional preamble (L-STF, L-LTF, L-SIG) readable by any legacy station, RL-SIG, HE-SIG-A, HE-STF, HE-LTF, Data and PE fields.

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 (DL) and uplink (UL) directions, once a transmission opportunity has been reserved and granted to the AP. In the uplink, multi-user transmissions can be used to mitigate the collision probability by allowing multiple non-AP stations to simultaneously transmit to the AP.

To actually perform such multi-user transmission, it has been proposed to split a granted 20MHz channel (400-1 to 400-4) into at least one sub-channel, but preferably into a plurality of sub-channels (elementary sub-channels), also referred to as sub-carriers or resource units (RUs) or “traffic channels”, 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 5**.

The multi-user feature of OFDMA allows the AP to assign different RUs to different stations in order to increase competition within a reserved transmission opportunity TXOP. This may help to reduce contention and collisions inside 802.11 networks.

In this example, each 20 MHz channel (400-1, 400-2, 400-3 or 400-4) is subdivided in the frequency domain into four OFDMA sub-channels or RUs 510 of size 5MHz. Of course the number of RUs splitting a 20 MHz channel may be different from four, and the RUs may have different sizes. For instance, between two to nine RUs may be provided (thus each having a size between 10 MHz and about 2 MHz). It is also possible to have a RU width greater than 20 MHz, when included inside a wider composite channel (e.g. 80 MHz).

Regarding the MU downlink transmission (from the AP to the stations), the AP can directly send multiple data to multiple stations in the RUs, by simply providing specific indications within the preamble header of the PPDU sent during the TXOP, and then sending data in the data field.

Figure 2c illustrates the HE MU (Multi-User) PPDU format (HE-MU) used in 802.11ax for transmissions to one or more stations, in particular for MU downlink transmissions from AP to a plurality of stations.

The HE-MU PPDU includes the same preamble as the non-HT PPDU (**Figure 2a**) which is always transmitted at low bit rate. This is for all the devices, especially the legacy ones not implementing 802.11ac/ax, to be able to understand the preamble for any of the transmission modes.

Since multiple stations are intended recipients or addressees of the OFDMA downlink transmissions, the AP needs to tell the stations in which resource unit they will find their data. To achieve such signaling, 802.11ax provides the HE-SIG-B field 200 as shown in the Figure in which stations are assigned to RUs.

The SIG-B field 200 is only found in the downlink HE-MU-PPDU and contains two types of fields as shown in **Figure 2e**: a single Common Block field 220 and one or more User Specific fields 230.

The single Common Block field 220 defines, through an RU allocation field, the RU distribution for the current transmission opportunity (the other fields are of less importance). The format substantially follows the same format as the RU allocation provided in a Trigger Frame as introduced below.

802.11ax defines a set of predefined RU allocation schemes for 20MHz channels as shown in **Figure 2f**. The RU allocation field of Common Block field 220 thus references N 8-bit indexes pointing to entries of table of **Figure 2f**.

Each such entry defines an RU allocation scheme, i.e. how the 20MHz channel is split into consecutive RUs. The entry gives precisely the position (according to frequency increasing order), the size in terms of tones and the frequency range of each RU inside an MU transmission.

For instance, the first entry (index=00000000) defines nine 26-tone-width RUs at positions #1 to #9. The frequency band of RU at position #i is thus from the $[26*(i-1)+1]^{\text{th}}$ tone to the $(26*i)^{\text{th}}$ tone of the considered 20MHz channel. If the AP wants to define a plurality of RUs having this specific distribution, the RU allocation field of Common Block field 220 is set to value 00000000.

The 12th entry (index=00001011) of the table of predefined RU allocation schemes defines for instance a first 52-tone-width RU (position #1), followed by second, third and fourth RUs with a 26-tones width (positions #2, #3 and #4), followed by fifth and sixth RUs with a 52-tones width (position #5 and #6).

The User Specific fields 230 define information related to each RU defined in the Common Block field, and are provided in the same order as the RUs are successively defined in the Common Block field. For instance, the nth declared User Specific field 230 gives information about the nth RU as defined in the Common Block field, i.e. RU at position #n.

Each User Specific field 230 includes the AID of the addressee station ('STA-ID' field; provided by the AP during the association procedure of **Figure 3**), and also other information such as modulation and coding schemes, spatial streams, etc., which are of less importance here.

As only a single RU can be allocated to a given station, the signaling that enables a station to decode its data is carried in only one User Specific field (corresponding to the single RU).

Based on the resource distribution provided in the Common Block field and each corresponding User Specific field, a station can easily know which resource unit has been allocated to it and thus in which RU it will receive its data from the AP.

The HE-SIG-B is encoded on a per-20 MHz basis using BCC and is sent on the station's preferred band so that the station's signaling information is sent on the same band as the payload.

Things are different for the MU uplink transmissions, because the AP must control when and how (in which RU) the stations must emit data.

Contrary to the MU downlink transmission, a trigger mechanism has been adopted for the AP to trigger MU uplink communications from various non-AP stations. This is for the AP to have such control on the stations.

To support a MU uplink transmission (during a TXOP pre-empted by the AP), the 802.11ax AP has to provide signalling information for both legacy stations (i.e. non-802.11ax stations) to set their NAV and for 802.11ax stations to determine the Resource Units allocation.

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

As shown in the example of **Figure 5**, the AP sends a trigger frame (TF) 530 to the targeted 802.11ax stations to reserve a transmission opportunity. The bandwidth or width of the

targeted composite channel for the transmission opportunity is signalled in the TF frame, meaning that the 20, 40, 80 or 160 MHz value is signalled.

The TF frame is a control frame, according to the 802.11 legacy non-HT format shown in **Figure 2a**, and is sent over the primary 20MHz channel and duplicated (replicated) on each other 20MHz channels forming the targeted composite channel. Due to the duplication of the control frames, it is expected that every nearby legacy station (non-HT or 802.11ac stations) receiving the TF on its primary channel, then sets its NAV to the value specified in the header of the TF frame. This prevents these legacy stations 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) 510. The multi-user feature of OFDMA allows the AP to assign different RUs to different stations in order to increase competition. This may help to reduce contention and collisions inside 802.11 networks.

The information about the RU distribution in the requested transmission opportunity and about the assignment of stations to the RUs is indicated in the payload of the MAC frame carried in the Data field (shown in **Figure 2a**). Indeed, the MAC payload is basically empty for classical control frames (such as RTS or CTS frame), but is enhanced with an information structure for Trigger Frames: an RU allocation field defines the allocated RUs (i.e. RU distribution in the TXOP) while one or more User Info fields indicates the information related to each respective RU (in the same order as provided by the RU allocation info field). In particular, the Address field in each User Info field provides the AID of the station to which the corresponding RU is assigned.

These various fields are similar to those (Common Block and User Specific) defined above with reference to **Figures 2e** and **2f**.

The trigger frame 530 may define "Scheduled" RUs, which may be reserved by the AP for certain stations in which case no contention for accessing such RUs is needed for these stations. Such scheduled RUs and their corresponding scheduled stations are indicated in the trigger frame (the Address field of the User Info field for the scheduled RU is set to the AID of the station). This explicitly indicates the station that is allowed to use each Scheduled RU. Such transmission mode is concurrent to the conventional EDCA mechanism.

If a station finds that there is no User Info field for Scheduled RUs in the Trigger frame 530 carrying its AID in its Address field, then the station should not be allowed to transmit in a Scheduled RU of the TXOP triggered by the TF.

The trigger frame TF 530 may also designate "Random" RUs, in addition or in replacement of the "Scheduled" RUs. The Random RUs can be randomly accessed by stations. In other words, Random RUs designated or allocated by the AP in the TF may serve as basis for contention between stations willing to access the communication medium for sending data. A collision occurs when two or more stations attempt to transmit at the same time over the same RU.

Such random RUs are signalled in the TF by using specific reserved AID in the Address field of the User Info field corresponding to the RU. For instance, an AID equal to 0 is used to identify random RUs available for contention by stations associated with the AP emitting the trigger frame (i.e. belonging to the same BSS). On the other hand, an AID equal to 2045
 5 may be used to identify random RUs available for contention by not-yet-associated stations (i.e. not belonging to the same BSS as the AP sending the TF 530).

Note that several random RUs with AID=0 and/or with AID=2045 may be provided by the same TF.

A random allocation procedure may be considered for 802.11ax standard based on
 10 an additional backoff counter (OFDMA backoff counter, or OBO counter or RU counter) for random RU contention by the 802.11ax non-AP stations, i.e. to allow them for performing contention between them to access and send data over a Random RU. The RU backoff counter is distinct from the classical EDCA backoff counters (as defined in 802.11e version). However data transmitted in an accessed OFDMA RUs 510 is assumed to be served from same EDCA
 15 traffic queues.

The RU random allocation procedure comprises, for a station of a plurality of 802.11ax stations having an positive RU backoff value (initially drawn inside an RU contention window range), a first step of determining, from a received trigger frame, the sub-channels or RUs of the communication medium available for contention (the so-called "random RUs", either
 20 identified by a value 0 for already-associated stations or a value 2045 for not-yet-associated stations), a second step of verifying if the value of the RU backoff value local to the considered station 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 to then send data. In case the second step is not verified, a fourth step (instead
 25 of the third) is performed in order to decrement the RU backoff counter by the number of detected-as-available random RUs.

As one can note, a station having no Scheduled RU is not guaranteed to perform OFDMA transmission over a random RU for each TF received. This is because at least the RU backoff counter is decremented upon each reception of a Trigger Frame by the number of
 30 proposed Random RUs, thereby differing data transmission to a subsequent trigger frame (depending of the current value of the RU backoff number and of the number of random RUs offered by each of further received TFs).

Back to **Figure 5**, it results from the various possible accesses to the RUs that some of them are not used (510u) because no station with an RU backoff value less than the
 35 number of available random RUs has randomly selected one of these random RUs, whereas some other RUs have collided (as example 510c) because at least two of these stations 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 Uplink transmission of data by the stations in the RUs 510 is made using HE Trigger-Based PPDU (HE_Trig) as shown in **Figure 2d** in each RU accessed by the stations. Each HE-Trig PPDU carries a single transmission (i.e. from one station to the AP) in response to the trigger frame 530. This HE-Trig PPDU frame format has a format quite similar to the one of HE SU PPDU, except the duration of the HE-STF field is 8 μ s.

Once the stations have used the Scheduled and/or Random RUs to transmit data to the AP, the AP responds with a Multi-User acknowledgment (not shown in **Figure 5**) to acknowledge the data received on each RU.

The MU Uplink (UL) medium access scheme, including both scheduled RUs and random RUs, proves to be very efficient compared to conventional EDCA access scheme, especially in dense environments as envisaged by the 802.11ax standard. This is because the number of collisions generated by simultaneous medium access attempts and the overhead due to the medium access are both reduced.

Figure 6 illustrates, through an exemplary situation of data transmission in a WLAN, drawbacks of the current version of 802.11ax.

In this exemplary situation, the wireless network comprising a physical access point 110 and a plurality of associated stations STA2, STA3, STA4, STA5, STA7 and STA8 and a plurality of not-yet-associated 802.11ax stations STA1 and STA6.

The AP 110 emits periodically a beacon frame 610, containing parameters of WLAN/BSS group(s).

All stations (including the AP) contend for an access to the wireless network using conventional EDCA scheme. The contention process (EDCA backoff counters) at each station starts or restarts each time the wireless network is detected as idle for a predefined time period (usually DIFS time period after the end of a previous TXOP, for instance after an acknowledgment from the AP or after end of a PPDU transmission).

When accessing to the medium, the AP 110 sends a trigger frame 530 to reserve a MU UL transmission opportunity (TXOP#1) on at least one communication channel of the wireless network. The trigger frame 530 defines resource units for the MU Uplink OFDMA transmission in TXOP#1, including one or more random RUs associated with AID=2045 (i.e. dedicated or assigned to not-yet-associated stations like STA1 and STA6). This is for the not-yet-associated stations to speed up their association procedure, while reducing medium access and occupancy. In the example, two random RUs with AID=2045 are provided, the other RUs being Scheduled RUs and/or random RUs with AID=0.

In response to the TF 530, the AP receives data on the RUs 510 from one or more stations during the MU Uplink OFDMA transmission time. This includes data transmitted over Scheduled RUs but also over Random RUs.

In particular, the AP may receive request management frames (e.g. 310, 340, 360) from not-yet-associated 802.11ax stations such as STA1 and STA6, over the Random RUs with AID=2045.

Upon receiving the data and management frames over the RUs 510 forming the MU Uplink OFDMA transmission, the AP 110 responds with a Multi-STA BlockAck Frame 640 using a HE SU PPDU (having a “receiving address” RA field set with a broadcast address). Note that in the AP acknowledges receipt to each sending station by providing, in the Multi-STA BlockAck Frame, the AID of the sending station for which data have been correctly received. As

5 no AID has been associated with each not-yet-associated station, the Multi-STA BlockAck Frame is modified to receive the MAC address of each not-yet-associated station for which the requested management frame has been correctly received.

Next to TXOP#1, the AP 110 may again gain access to the medium for a new

10 TXOP, referred to as TXOP#2, to perform a MU Downlink OFDMA transmission.

The RUs provided for the MU Downlink OFDMA transmission are assigned to specific stations using their AID. In the present example, the RUs are successively assigned to STA3, STA5, STA4, STA2, STA8 and STA7.

For some stations, here STA2 and ST8, the amount of data to transmit is small

15 regarding the size of the reserved RU. As a consequence, padding data (black portions) are added by the AP 110 to keep sufficient activity on the 20MHz channel (for detection by legacy nodes in order to avoid unexpected access). The black portions of the RUs shown in the Figure illustrate how the padding wastes bandwidth of the network.

The AP 110 may also have received a multicast MAC frame from another network

20 or from upper OSI layer, to be addressed to a plurality of addressee stations, here STA4 and STA5.

Multicast addressing can be used in the link layer, such as Ethernet multicast, and at the Internet layer (as example, IP protocol includes the addresses from 224.0.0.0 to 239.255.255.255 as a multicast range).

As 802.11ax does not provide any mechanism to allow multicast traffic in a MU

25 Downlink OFDMA transmission, the AP has to duplicate the MAC frame into two HE-MU PPDUs to be transmitted over two separate RUs as shown in the Figure. This also wastes bandwidth, in particular because of the costs of signalling two separate RUs.

Also, as the AP may only assign an AID to an RU of the MU Downlink OFDMA

30 transmission, the AP cannot use the MU Downlink OFDMA transmission to provide response management frames (e.g. 320, 350, 370) to the not-yet-associated stations, here STA1 and STA6. In the current version of 802.11ax, the MU Downlink OFDMA transmission is restricted to already-associated stations. It means that the response management frames (from the AP to the stations) are still to be conveyed using the legacy single user (SU) mode: for instance, the

35 AP 110 waits until accessing again the medium for a new TXOP (here TXOP#3), during which the AP 110 sends for instance a probe response frame 320 to STA1 using an HE SU PPDU 630-1; and waits again until accessing again the medium for another TXOP (here TXOP#4), during which the AP 110 sends for instance an authentication response frame 350 to STA6

using an HE SU PPDU 630-2. In all cases, an acknowledgment ACK 330 may be received from the addressee station.

The need to use HE SU PPDU for handling the response management frames is not satisfactory: on one hand, it introduces delays in the network management because the AP
 5 110 has to contend for new accesses to the network; on the other hand, it inefficiently uses the medium for a long time, given the few data to be transmitted, because the HE SU PPDU are send at low bit rate.

These various drawbacks of the current version of 802.11ax show that a more efficient usage of the MU Downlink transmission is sought.

10 The inventors have contemplated using RUs in the MU Downlink transmission for multiple addressee stations, i.e. resource units dedicated to respective pluralities of stations. The access point can thus aggregate data frames addressed to two or more stations, and transmit the aggregated data frames over such a resource unit dedicated to a plurality of stations, from amongst a plurality of resource units forming the multi-user downlink transmission
 15 opportunity (MU Downlink OFDMA TXOP) granted to the access point for downlink communication to the stations.

For instance, such RUs for groups of stations may be signaled using "group AIDs", contrasting with current requirements that allows only individual AIDs (i.e. associated with a single station) to be used for MU Downlink transmission. In particular, the resource unit
 20 dedicated to a plurality of stations may thus be assigned in the downlink transmission opportunity to a predefined (group) association identifier not associated with a specific station.

As a consequence, any station (concerned by such a group) may determine (e.g. using group AIDs) a resource unit dedicated to a plurality of stations, from amongst a plurality of resource units forming a multi-user downlink transmission opportunity granted to the access
 25 point for downlink communication to the stations, receive aggregated data frames over the determined resource unit; and retrieve one or more data frames addressed to the station, from amongst the received aggregated data frames.

In fact, where any station registering with the access point being associated with a unique association identifier used by the access point to assign, to the station, a resource unit in
 30 a transmission opportunity granted to the access point, an idea of the invention consist for the AP to build a plurality of resource units forming a multi-user downlink transmission opportunity granted to the access point for downlink communication to the stations, the plurality of resource units comprising a resource unit assigned to an association identifier not associated with a specific station; and then transmit one or more data frames to a station on the resource unit
 35 assigned to an association identifier not associated with a specific station.

So the station only determines a resource unit assigned to an association identifier not associated with a specific station, from a plurality of resource units forming a multi-user downlink transmission opportunity granted to the access point for downlink communication to

the stations; and thus receives one or more data frame from the access point on the determined downlink resource unit.

By aggregating data frames to be addressed to several stations within the same dedicated RU, the invention make it possible for the AP to efficiently target a large number of stations, thereby using more efficiently each RU (and thus reducing padding bits), avoiding
 5 duplicating the same payload over several RUs (by grouping the stations targeted by the same multicast frame) and efficiently (i.e. at a higher bit rate) providing response management frames to the not-yet-associated stations (thus forming a group of not-associated stations).

Also, by using AID not associated with stations during MU Downlink transmissions,
 10 the invention offers the AP with the opportunity to address one or more stations deprived of AID. An RU assigned to an association identifier not associated with a specific station may thus be dedicated to a plurality of stations. The stations may thus easily identify, in a Downlink transmission, which RU to listen to.

MU Downlink transmission is thus significantly improved compared to known
 15 current 802.11ax requirements.

Figure 7 schematically illustrates a communication device 700, either a non-AP station 101-107 or the access point 110, of the radio network 100, configured to implement at least one embodiment of the present invention. The communication device 700 may preferably be a device such as a micro-computer, a workstation or a light portable device. The
 20 communication device 700 comprises a communication bus 713 to which there are preferably connected:

- a central processing unit 711, such as a microprocessor, denoted CPU;
- a read only memory 707, denoted ROM, for storing computer programs for implementing the invention;
- 25 • a random access memory 712, 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 702 connected to the radio
 30 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 712 to the network interface for transmission or are read from the network interface for reception and writing into a FIFO receiving memory in RAM 712 under the control of a software application running in the CPU
 35 711.

Optionally, communication device 700 may also include the following components:

- a data storage means 704 such as a hard disk, for storing computer programs for implementing methods according to one or more embodiments of the invention;

- a disk drive 705 for a disk 706, the disk drive being adapted to read data from the disk 706 or to write data onto said disk;

- a screen 709 for displaying decoded data and/or serving as a graphical interface with the user, by means of a keyboard 710 or any other pointing means.

5 The communication device 700 may be optionally connected to various peripherals, such as for example a digital camera 708, each being connected to an input/output card (not shown) so as to supply data to the communication device 700.

10 Preferably the communication bus provides communication and interoperability between the various elements included in the communication device 700 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 700 directly or by means of another element of the communication device 700.

15 The disk 706 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.

20 The executable code may optionally be stored either in read only memory 707, on the hard disk 704 or on a removable digital medium such as for example a disk 706 as described previously. According to an optional variant, the executable code of the programs can be received by means of the communication network 703, via the interface 702, in order to be stored in one of the storage means of the communication device 700, such as the hard disk 704, before being executed.

25 The central processing unit 711 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 704 or in the read only memory 707, are transferred into the random access memory 712, 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.

30 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).

35 **Figure 8** is a block diagram schematically illustrating the architecture of the communication device 700, either the AP 110 or one of stations 101-107, adapted to carry out, at least partially, the invention. As illustrated, device 700 comprises a physical (PHY) layer block 803, a MAC layer block 802, and an application layer block 801.

The PHY layer block 803 (here an 802.11 standardized PHY layer) has the task of formatting, modulating on or demodulating from any 20MHz 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 TF 530 (**Figure 5**) to reserve a transmission slot, 5 MAC data and management frames based on a 20MHz width to interact with legacy 802.11 stations, as well as of MAC data frames of OFDMA type having smaller width than 20MHz legacy (typically 2 or 5 MHz) to/from that radio medium.

The MAC layer block or controller 802 preferably comprises a MAC 802.11 layer 804 implementing conventional 802.11ax MAC operations, and additional block 805 for carrying 10 out, at least partially, the invention. The MAC layer block 802 may optionally be implemented in software, which software is loaded into RAM 712 and executed by CPU 711.

Preferably, the additional block 805, referred to as multiple station RU management module for controlling usage of Downlink OFDMA resource units (sub-channels), implements the part of embodiments of the invention (either from station perspective or from AP 15 perspective).

For instance and not exhaustively, the operations for the AP may include generating and sending MU Downlink frames as defined below, which MU Downlink frames identify, using specific AIDs, at least one RU dedicated to a plurality of stations instead of a single station per RU as currently done; and then managing the aggregation of MAC frames to 20 be addressed to stations of the plurality inside such resource unit. The operations for a station different from the AP may include analyzing received MU Downlink frame to determine if the station is allowed to access an RU for itself or an RU dedicated to a plurality of stations, and in the context of such an RU dedicated to a plurality of stations, processing the MAC frames aggregated therein to retrieve the or those MAC frames addressed to it.

25 MAC 802.11 layer 804, multiple-station-RU management module 805 interact one with the other in order to process accurately communications over Downlink OFDMA RU addressed to multiple stations according to embodiments of the invention.

On top of the Figure, application layer block 801 runs an application that generates and receives data packets, for example data packets of a video stream. Application layer block 30 801 represents all the stack layers above MAC layer according to ISO standardization.

Embodiments of the present invention are now illustrated using various exemplary embodiments in the context of IEEE 802.11ax by considering OFDMA RUs dedicated to multiple stations.

Although the proposed examples are also mainly described with reference to the 35 management frames of the 802.11 association process, the present invention is not limited to such management frame transmission but also any 802.11 data frame such as those addressed to various stations.

Figure 9a illustrates, using a flowchart, embodiments of the invention implemented at a physical access point when preparing and performing a MU Downlink transmission.

At step 910, the AP first determines if it is willing to group several addressee stations for a Downlink transmission.

Three exemplary situations are proposed here.

5 In the case of station association procedure, stations may send request management frames to the access point within procedures of associating (i.e. registering) the station with the access point. In other words, the access point may receive request management frames (310, 340, 360) from stations willing to associate (i.e. register) with the access point, and intends to answer to those stations by grouping together the response management frames (320, 350, 370) in the same RU according to the invention.

10 The request management frames may have been received either or both via previous Single User communications or via a previous Trigger Frame emitted by the AP (typically the TF 530 as regards to the **Figure 6**), such trigger frame allocating some random RUs with an AID equal to 2045 value in order that some request management frames are sent by not-yet-associated stations in corresponding RU during the Uplink transmission phase 510.

15 Also, the AP may group stations with regards to a common interest to receive data frames. For instance, the access point receives a multicast frame (e.g. from an upper OSI layer) to be addressed to a plurality of addressee stations, and may thus consider forwarding the multicast frame to the addressee stations using an RU dedicated to this plurality of stations.

20 Another example is the case where the access point determines there are small data frames to be transmitted to stations, given a size of the downlink transmission opportunity and a size threshold (and possibly the size of RUs), that could be grouped into a single RU to reduce padding bits. More generally, the AP may consider using a special group to convey any MAC frame (to be transmitted) which does not belong to an existing individual transmission of the MU Downlink transmission. The AP may for instance seek to use the individual RUs to
25 convey the largest MAC frames, in order to fill an "MPDU collector" RU or "collecting RU" with the maximum of remaining MAC frames (that are smaller).

As example, the collecting RU may collect any pending MAC frame stored in an EDCA buffer of the AP, and for which an assignment of an individual RU is not efficient (too much padding needed – for instance STA3 and STA8 in **Figure 6**).

30 Once the AP has determined one or more groups of addressee stations with the corresponding MAC frames to be transmitted, an RU is assigned to each group so determined, at step 920.

For instance, an RU may be allocated to convey the response management frames (320, 350 or 370) in response to requests previously received from not-yet-associated stations.

35 In a preferred embodiment, the AID value assigned to this RU for multiple stations takes the predefined value 2045 (known by all 802.11ax nodes compliant with the present invention). One may note that this value is the same value as used to indicate the RU dedicated or assigned to not-yet-associated stations in the MU Uplink transmission (510 in **Figure 6**), to speed up their association procedure.

As a consequence, if a request management frame is sent (by a station) in a prior resource unit forming part of an uplink transmission opportunity granted to the access point for uplink communication from the stations, the prior resource unit being assigned to stations not yet associated with the access point, the resource unit assigned at step 920 and the prior resource unit used are signalled in the downlink and uplink transmission opportunities respectively, using the same prefixed association identifier (not provided to a specific station by the AP), here AID=2045.

One may note that, even without aggregating MAC frames in the RU dedicated to not-yet-associated stations, the sole idea of providing an RU with an AID reserved for not-yet-associated stations for Downlink transmission improves (speeds up) the association procedure for such stations. Such RU may be used for a single not-yet-associated station.

An RU may also be assigned to convey the multicast frame intended to several addressee stations. A predefined AID may be used in this respect, for instance AID=2042 known by all the 802.11ax nodes compliant with the present invention.

Also, the collecting RU to collect small pending MAC frames may be signaled using AID=0.

Other variants may be proposed. For instance, in the context of multiple BSSs ("virtual APs") managed by a single physical AP, the AP may assign a unique AID value to respectively each of the BSSs it manages, meaning each BSS has a unique AID value not associated with a specific station (but with the whole BSS). For instance, the AID value may be the index of each BSS : if 'n' is the maximum number of virtual APs managed by the physical AP (as example, this value is specified in the MaxBSSID Indicator in the Multiple BSSID element of beacon and probe response frames), then AIDs 1 to n are assigned to respectively BSSs 1 to n.

Each non-representative AP can use only its own AID. However, the representative AP can use any AID of the VAPs.

In this context, the representative AP may provide, in a MU Downlink transmission, one or more collecting RUs specific to one or more respective BSSs, by using the respective AIDs. The AP may thus select the AID of the BSS for which it is about to transmit frames.

Also, the representative AP may signal random RUs in a TF (MU Uplink transmission) assigned respectively and individually to specific BSSs: first random RUs are assigned to AID=i to restrict the access to not-yet-associated stations willing to register with VAP i, while second random RUs are assigned to AID=j to restrict the access to not-yet-associated stations willing to register with VAP j. RUs having the same AIDs can be used in the MU Downlink transmission to transmit the response management frames related to each BSS.

Once the one or more RUs dedicated to groups of stations have been determined, step 930 consists for the AP in concatenating or aggregating, for each RU, all the pending MPDU frames for the corresponding group of stations.

For the management frames, all the response MAC management frames prepared by the AP for the not-yet-associated stations can be aggregated together into an HE-MU PPDU (up to the size of the PPDU given the reserved TXOP).

For the multicast frame, responsive to the multicast frame reception, the access point may generate a plurality of data frames including payload of the multicast frame, to be each individually addressed to a respective one of the addressee stations. The AP thus aggregates the generated data frames including payload of the multicast frame (up to the size of the PPDU given the reserved TXOP). Of course, if the TXOP does not provide enough space to transmit all the generated data frames, the remainder may be transmitted during one or more next MU Downlink transmissions.

Also, the AP may aggregate together (and up to the size of the PPDU given the reserved TXOP) the MAC frames stored in its EDCA buffers for stations that have not yet been addressed by other RUs of the same MU Downlink transmission. Given this constraint, the aggregation for the collecting RU is processed at the end (as the last RU).

The AP may follow the principle of 802.11ax A-MPDU aggregation for classical RU, but slightly modify it to allow MPDUs of the same A-MPDU to be addressed to different stations.

Any other aggregation mechanism (MAC Service Data Unit (MSDU) aggregation, MAC Protocol Data Unit (MPDU) aggregation, concatenation of A-MPDU frames, or any combination of those schemes) can be used to concatenate MAC frames for various stations.

To make it possible for the stations to efficiently retrieve their own MAC frames, the access point sets, in each data frame to be aggregated, a MAC address field to a MAC address of the addressee station.

Next at step 940, the MU Downlink PPDU formed of each RU is sent by the AP on the corresponding RU of the communication channel.

Regarding the groups of stations, it means that the aggregated response management frames are transmitted on the RU with AID=2045 or on each RU with AID=i for the response management frames related to BSS i (in case of multi-BSSs); the aggregated generated frames including the payload data of the multicast frame are transmitted over the RU with AID=2042 as example; and the aggregated collected frames are transmitted over the last RU of the channel, the RU with AID=0 (possibly with AID=j for collected frames related to specific BSS i in case of multi-BSSs).

The other RUs (assigned to individual stations) are handled conventionally.

To ensure efficient processing by the stations, the downlink transmission opportunity may include an ordered signalling (in the HE-SIG-B preamble of 802.11ax MU DL frame) of assignments of resource units of the plurality to one or more stations, the ordered signalling first defining each assignment of a resource unit to an individual station (RU with an AID associated with a single station), next defining each assignment of a resource unit to a group of stations (AID=2042 or 2045 or i in case of multi-BSSs, in the examples above), then defining an assignment of the collecting resource unit (AID=0) to any station not yet associated

with a resource unit. This advantageously allows a station to disregard any further RU analysis in the same HE MU PPDU once it has found one RU (individual or group) addressed to it.

One may note that the invention advantageously keeps the strict usage of a unique AID presence in the RU Allocation of the HE-SIG-B preamble, despite the use of groups of stations or the transmission to (not-yet-associated) stations having no AID.

The Downlink transmission opportunity thus includes resource units that the stations may read using a conventional 802.11ax scheme (e.g. by identifying the RU linked with their AID) or by using the invention scheme (e.g. by identifying a RU linked with a group AID) as now described with reference to **Figure 9b**.

Figure 9b illustrates, using a flowchart, embodiments of the invention implemented at a non-AP station to handle RUs dedicated to groups of stations in MU Downlink transmissions from the AP.

The non-AP station can be any station already associated with the AP emitting the MU Downlink PPDU, or any not-yet-associated station which is in the process of associating with the AP emitting the MU Downlink PPDU.

At step 950, a MU Downlink frame made of per-RU PPDU is received from the physical access point, and the station determines which RU is addressed to it. RUs assigned to individual stations are processed conventionally.

Embodiments of the invention are directed to the situation where the station is involved in a RU conveying data for a group of stations. In that case, the station determines such a resource unit dedicated to a plurality of stations, from amongst a plurality of resource units forming the downlink transmission opportunity granted to the access point for downlink communication to the station.

For a not-yet-associated station, it means determining a resource unit assigned to stations not yet associated with the access point. This is to retrieve a response management frame from the access point to the sent request management frame. This may be simply performed by searching in the HE-SIG-B preamble of the received MU Downlink frame for an RU with an AID equal to 2045 or an RU with an AID equal the BSSID (in case of multi-BSSs).

If no RU is found, the process ends and the not-yet-associated station set its NAV (duration is obtained from L-SIG field of the received frame).

If such RU with AID=2045 is found, next step is step 960.

Optionally, the not-yet-associated station may analyze the received MU Downlink frame, and thus determine a resource unit assigned to stations not yet associated, only if a request management frame sent by the station is pending (i.e. no response has been received from the AP). This request may have been previously transmitted during a prior MU Uplink transmission (for instance during 510).

For an already-associated station, the operations may be different. The station may first scan through resource units assigned to individual stations to verify whether a resource unit in the received MU Downlink frame is individually assigned to the station or not,

and in case of negative verification only, the station determines a resource unit dedicated to a plurality of stations from the not-yet scanned resource units of the plurality.

Such processing order derives from the order of declaring the RUs in the MU Downlink frame as indicated above with reference to **Figure 9a**: the individual RUs are first declared, followed by the group RUs (AID=2042 for instance for multicast), followed by the collecting RU (AID=0). In this situation, if the station detects a single RU addressed to it, the process of **Figure 9b** ends and the station analyzes the corresponding RU in a conventional 802.11ax way. Otherwise, the station searches between the group RUs if one of them is addressed to it. This may be performed using bit masking on the AID (for instance if group AID have the same most significant bits) and/or by detecting predefined AIDs. Thus, the station scans through resource units assigned to lists (groups) of stations to verify whether the station belongs to a list associated with one of the scanned (group) resource units.

This makes it possible for the station to stop analyzing the MU Downlink frame as soon as an RU addressed to it is detected. For instance, if the station knows it is involved in a multicast communication (e.g. due to exchange at an application layer – see module 801), the station may scrutinize any RU dedicated to multicast (AID=2042 in the example here).

In case of positive verification (the station belongs to a list), the determined resource unit to retrieve the data frames is the one assigned to the list that includes the station (e.g. with AID=2042).

On the other hand, in case of negative verification only, the determined resource unit is the collecting resource unit (AID=0) used to convey data frames for any station not assigned, individually or through a list, to another resource unit forming the downlink transmission opportunity. The station will thus monitor the collecting RU.

Of course, any other order for considering the RUs may be implemented, so that the station may decide to stop its analysis upon either the detection of a single RU addressed to it or a group RU addressed to it.

Finally, if a group RU is found (AID=2042, 2045 or 0 in the above examples), step 960 is executed where the station reads the determined RU and thus receives aggregated data frames from the AP. All the MPDUs forming the A-MPDU received on the determined RU are provided to the MAC layer (process 805) for further analysis.

At step 970, the station compares a MAC address of each aggregated data frame (the RA field of each MPDU forming the A-MPDU) with its own MAC address. This is to retrieve one or more data frames, if any, addressed to the station, from amongst the received aggregated data frames.

Symmetrically to what has been made at the AP, the principle of 802.11ax A-MPDU deaggregation for classical RU is slightly modify at the station to analyze the MAC address of each MPDU. This is to avoid stopping the de-aggregation process as soon as one MPDU not matching the receiver station address is found, as done with legacy A-MPDU processing.

The station then keeps only the MPDU or MPDUs having a MAC address equal to the station's MAC address.

Next, at step 980, all extracted MPDUs addressed to the stations are forwarded to upper layer stacks (for instance to the application layer 801).

5 The station may not acknowledge receipt of the retrieved data frames, to the access point (no additional step is shown in the Figure). Thus, all MU Downlink MPDU transmitted in the RU dedicated to a group of stations contain a No-Ack indication.

 Optionally, an acknowledgment policy may be implemented. However, as several stations are involved in the same RU while a single station only may acknowledge receipt of data, a specific strategy is proposed: the station may send an acknowledgment of the retrieved data frames only if the retrieved data frames include the last received aggregated data frame. It means that only the last MPDU in the A-MPDU is explicitly acknowledged by its addressee station (according to 802.11ax standard, in an RU of MU ACK following the MU Downlink frame in the same TXOP). As a consequence, the other MPDUs may be implicitly acknowledged by
15 the acknowledgment of the last MPDU.

 In the specific case of not-yet-associated stations receiving a response from the AP, an acknowledgment of the retrieved response may be sent by the receiving station, in a next resource unit forming part of a next uplink transmission opportunity granted to the access point for uplink communication from the stations, the next resource unit being assigned to stations not yet associated with the access point (i.e. a next random RU with AID=2045 in an MU Uplink TXOP).
20

 To improve network efficiency, this acknowledgment may further be aggregated in this next RU (with AID=2045 for instance) with any further request management frame. For instance, if a probe response frame 320 is received in the MU Downlink frame according to the invention, then the station may provide the acknowledgement 330 corresponding to 320
25 together with the next request management frame (here authentication request frame 340), in an RU with AID=2045 in the next MU Uplink transmission 510. This is to make the association procedure progressing faster for the station.

Figure 10 illustrates the impact of the present invention on the exemplary situation
30 of **Figure 6** described above.

 TXOP#1 is the same through with not-yet-associated stations STA1 and STA6 send request management frames to the AP in the RU with AID=2045.

 As readily apparent from the HE-SIG-B preamble of MU Downlink frame 1020, group AIDs are used, in particular AID=0 (for collecting small frames), 2042 (for multicast) and
35 2045 (for not-yet-associated stations). As indicated above, the HE-SIG-B preamble may declare first the RUs for individual stations (here 2 and 7), followed by the group RUs (here 2042 and 2045), followed by the collecting RU (here 0) which is dedicated to "all other" associated stations.

The RU with AID=2045 is used to convey concatenated MPDU frames addressed to not-yet-associated stations, here a probe response frame intended to STA1 and an response authentication frame intended to STA6. As a consequence, successive SU transmissions (630-1 and 630-2 in **Figure 6**) for management frames are avoided, resulting in a simplification of the association procedure for not-yet-associated STAs and a more efficient usage of the network. This is particularly advantageous to manage the association of new stations in dense networks as 802.11ax.

The RU with AID=2042 is used to convey concatenated MPDU frames addressed to stations belonging to a multicast group, here stations STA5 and STA4. A single 802.11 A-MPDU frame is used and conveyed inside a single RU. This avoids RU duplication compared to conventional 802.11ax scheme.

The RU with AID=0 is used to convey concatenated small MPDU frames which individually would not efficiently fill an entire RU (even if of smallest band, e.g. 26 tones) or when the limitation of number of RUs (maximum 9 per 20Mhz band) is already reached. Such concatenation allows limiting padding in the RUs and thus reduces latency of small frames compared to conventional 802.11ax scheme.

As shown in the Figure, the MU Downlink frame 1020 is followed by an acknowledgment frame 1040 according to the 802.11ax standard (for instance, with no acknowledgment for group AIDs or with an acknowledgment from the station to which the last transmitted MPDU is addressed).

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 stations, the method comprising the following steps, at one of the stations:
 - 5 determining a resource unit dedicated to a plurality of stations, from amongst a plurality of resource units forming a multi-user downlink transmission opportunity granted to the access point for downlink communication to the stations;
 - receiving aggregated data frames over the determined resource unit; and
 - retrieving one or more data frames addressed to the station, from amongst the
 - 10 received aggregated data frames.
2. A wireless communication method in a wireless network comprising an access point and stations, the method comprising the following steps, at the access point:
 - aggregating data frames addressed to two or more stations; and
 - transmitting the aggregated data frames over a resource unit dedicated to a
 - 15 plurality of stations, from amongst a plurality of resource units forming a multi-user downlink transmission opportunity granted to the access point for downlink communication to the stations.
3. A wireless communication method in a wireless network comprising an access point and stations, any station registering with the access point being associated with a unique association identifier used by the access point to assign, to the station, a resource unit in a transmission opportunity granted to the access point, the method comprising the following steps, at one of the stations:
 - determining a resource unit assigned to an association identifier not associated with a specific station, from a plurality of resource units forming a multi-user downlink
 - 25 transmission opportunity granted to the access point for downlink communication to the stations; and
 - receiving one or more data frame from the access point on the determined downlink resource unit.
4. The method of Claim 3, further comprising, at the station:
 - 30 receiving aggregated data frames over the determined resource unit; and
 - retrieving one or more data frames addressed to the station, from amongst the received aggregated data frames.
5. A wireless communication method in a wireless network comprising an access point and stations, any station registering with the access point being associated with a unique association identifier used by the access point to assign, to the station, a resource unit in a transmission opportunity granted to the access point, the method comprising the following steps, at the access point:
 - 35 building a plurality of resource units forming a multi-user downlink transmission opportunity granted to the access point for downlink communication to the stations, the plurality

of resource units comprising a resource unit assigned to an association identifier not associated with a specific station; and

transmitting one or more data frames to a station on the resource unit assigned to an association identifier not associated with a specific station.

5 **6.** The method of Claim 5, further comprising, at the access point:
aggregating data frames to be addressed to two or more stations; and
transmitting the aggregated data frames over the resource unit assigned to an
association identifier not associated with a specific station.

10 **7.** The method of Claim 1 or 2, wherein any station registering with the access
point is associated with a unique association identifier used by the access point to assign, to the
station, a resource unit in a transmission opportunity granted to the access point, and the
resource unit dedicated to a plurality of stations is assigned in the downlink transmission
opportunity to a predefined association identifier not associated with a specific station.

15 **8.** The method of Claim 1 or 4, wherein retrieving one or more data frames
addressed to the station includes comparing a MAC address of each aggregated data frame
with a MAC address of the station.

9. The method of Claim 2 or 6, further comprising, at the access point, setting,
in each data frame to be aggregated, a MAC address field to a MAC address of the addressee
station.

20 **10.** The method of Claim 1 or 4, wherein the station does not acknowledge
receipt of the retrieved data frames, to the access point.

11. The method of Claim 1 or 4, further comprising, at the station, sending an
acknowledgment of the retrieved data frames only if the retrieved data frames include the last
received aggregated data frame.

25 **12.** The method of Claim 1 or 3, further comprising, at the station prior to
determining a resource unit, sending a management frame to the access point within a
procedure of associating the station with the access point,

30 wherein determining a resource unit includes determining a resource unit assigned
to stations not yet associated with the access point, to retrieve a response from the access point
to the sent management frame.

13. The method of Claim 2 or 5, further comprising, at the access point prior to
the step of transmitting data frames, receiving at least one management frame from a station
willing to associate with the access point,

35 wherein the transmitted data frames include a response to the received
management frame and are transmitted over a resource unit assigned to stations not yet
associated with the access point.

14. The method of Claim 12, wherein the management frame is sent in a prior
resource unit forming part of an uplink transmission opportunity granted to the access point for

uplink communication from the stations, the prior resource unit being assigned to stations not yet associated with the access point.

15 **15.** The method of Claim 14, wherein the determined resource unit and the prior resource unit are assigned, in the downlink and uplink transmission opportunities respectively, to the same prefixed association identifier not associated with a specific station.

16. The method of Claim 15, wherein the association identifier not associated with a specific station is a 11-bit identifier equal to 2045 or is an association identifier associated with a basic service set, for instance equal to the basic service set identifier of the basic service set.

10 **17.** The method of Claim 3 or 5, wherein the association identifier not associated with a specific station is a 11-bit identifier equal to 2045 or is an association identifier associated with a basic service set, for instance equal to the basic service set identifier of the basic service set.

15 **18.** The method of Claim 12, further comprising, at the station, sending an acknowledgment of the retrieved data frames, in a next resource unit forming part of a next uplink transmission opportunity granted to the access point for uplink communication from the stations, the next resource unit being assigned to stations not yet associated with the access point.

20 **19.** The method of Claim 1 or 3, further comprising, at the station, first scanning through resource units assigned to individual stations to verify whether a resource unit of the plurality is individually assigned to the station or not, and in case of negative verification only, determining a resource unit dedicated to a plurality of stations from the not-yet scanned resource units of the plurality.

25 **20.** The method of Claim 19, wherein determining a resource unit dedicated to a plurality of stations from the not-yet scanned resource units comprises first scanning through resource units assigned to lists of stations to verify whether the station belongs to a list associated with one of the scanned resource units.

21. The method of Claim 20, wherein in case of positive verification, the determined resource unit is the one assigned to a list that includes the station.

30 **22.** The method of Claim 20, wherein in case of negative verification only, the determined resource unit is a collecting resource unit used to convey data frames for any station not assigned, individually or through a list, to another resource unit forming the downlink transmission opportunity.

35 **23.** The method of Claim 2 or 6, further comprising, at the access point, receiving a multicast frame to be addressed to a plurality of addressee stations; and

 responsive to the multicast frame reception, generating a plurality of data frames including payload of the multicast frame, to be each individually addressed to a respective one of the addressee stations, wherein the aggregated data frames to be transmitted include the generated data frames including payload of the multicast frame.

24. The method of Claim 23, wherein the resource unit to transmit the aggregated data frames including the payload of the multicast frame is assigned in the downlink transmission opportunity to a prefixed association identifier not associated with a specific station equal to 2042.

5 **25.** The method of Claim 2 or 6, further comprising, at the access point, determining small data frames to be transmitted to stations, given a size of the downlink transmission opportunity and a size threshold,

 wherein the determined small data frames are aggregated and transmitted over the resource unit, referred to as collecting resource unit.

10 **26.** The method of Claim 22, wherein the collecting resource unit is assigned in the downlink transmission opportunity to a prefixed association identifier not associated with a specific station equal to 0.

27. The method of Claim 22, wherein the downlink transmission opportunity includes an ordered signalling of assignments of resource units of the plurality to one or more stations, the ordered signalling first defining each assignment of a resource unit to an individual station, next defining each assignment of a resource unit to a group of stations, then defining an assignment of the collecting resource unit to any station not yet associated with a resource unit.

28. 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
20 the method of Claim 1, 2, 3 or 5.

29. A wireless communication device forming station in a wireless network comprising an access point and stations, the device forming station comprising at least one microprocessor configured for carrying out the steps of:

 determining a resource unit dedicated to a plurality of stations, from amongst a
25 plurality of resource units forming a multi-user downlink transmission opportunity granted to the access point for downlink communication to the stations;

 receiving aggregated data frames over the determined resource unit; and

 retrieving one or more data frames addressed to the station, from amongst the received aggregated data frames.

30 **30.** A wireless communication device forming access point in a wireless network comprising an access point and stations, the device forming access point comprising at least one microprocessor configured for carrying out the steps of:

 aggregating data frames addressed to two or more stations; and

 transmitting the aggregated data frames over a resource unit dedicated to a
35 plurality of stations, from amongst a plurality of resource units forming a multi-user downlink transmission opportunity granted to the access point for downlink communication to the stations.

31. A wireless communication device forming station in a wireless network comprising an access point and stations, any station registering with the access point being

associated with a unique association identifier used by the access point to assign, to the station, a resource unit in a transmission opportunity granted to the access point, the device forming station comprising at least one microprocessor configured for carrying out the steps of:

- 5 determining a resource unit assigned to an association identifier not associated with a specific station, from a plurality of resource units forming a multi-user downlink transmission opportunity granted to the access point for downlink communication to the stations; and

receiving one or more data frame from the access point on the determined downlink resource unit.

- 10 **32.** A wireless communication device forming access point in a wireless network comprising an access point and stations, any station registering with the access point being associated with a unique association identifier used by the access point to assign, to the station, a resource unit in a transmission opportunity granted to the access point, the device forming access point comprising at least one microprocessor configured for carrying out the steps of:

- 15 building a plurality of resource units forming a multi-user downlink transmission opportunity granted to the access point for downlink communication to the stations, the plurality of resource units comprising a resource unit assigned to an association identifier not associated with a specific station; and

- 20 transmitting one or more data frames to a station on the resource unit assigned to an association identifier not associated with a specific station.



Application No: GB1706408.0 **Examiner:** Mr Daniel Davies
Claims searched: 1, 2, 7, 29, 30 & in part (8-16, 18-28) **Date of search:** 23 October 2017

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1, 2, 7 - 16 & 18 - 30	US 2016/0330300 A1 (JOSIAM et al.) See abstract; fig. 20; para. [0003], [0102], [0106], [0108], [0119], [0120], [0129], [0142] - [0145]
X	1, 2, 7 - 16 & 18 - 30	US 2016/0330714 A1 (HEDAYAT) See abstract; fig. 15; para. [0190], [0191], [0196].
X	1, 2, 8 - 16 & 18 - 30	WO 2016/141570 A1 (HUAWEI TECH CO LTD) See WPI abstract Accession number 2016-57880N; fig. 3A & 3B; pg. 1, lines 24 - 28; pg. 2, lines 3 - 12; pg. 6, line 21 - pg. 8, line 25.
X	1, 2, 7 - 16 & 18 - 30	US 2016/0285526 A1 (HEDAYAT) See abstract; fig. 7, 9, 11, 14A - 14C; para. [0061], [0063], [0064], [0072], [0073], [0075], [0076], [0104], [0107].

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^X :

Worldwide search of patent documents classified in the following areas of the IPC

H04B; H04W

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI, Patent Fulltext



International Classification:

Subclass	Subgroup	Valid From
H04W	0072/04	01/01/2009
H04B	0007/0452	01/01/2017
H04W	0084/12	01/01/2009