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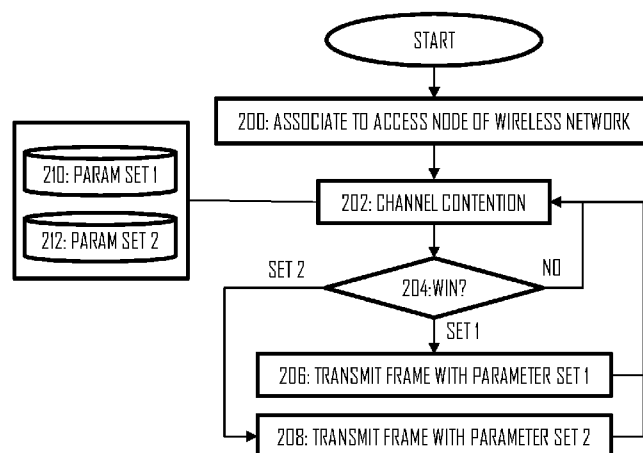


Fig 2

(57) Abstract: This document discloses a solution for determining transmission parameters in connection with channel contention. According to an aspect, a method comprises: associating, by a wireless device, to an access node of a wireless network; performing, by the wireless device during the association on a channel of the wireless network, channel contention for channel access separately for a plurality of parameter sets of the association, wherein the plurality of parameter sets comprise different combinations of at least one transmission parameter and at least one access parameter, and wherein the at least one access parameter is used in the channel contention; winning, by the wireless device, the channel contention on a parameter set of the plurality of parameter sets and, thus, acquiring a transmission opportunity; and transmitting, by the wireless device, a frame during the transmission opportunity to the access node by using the at least one transmission parameter of the parameter set.

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Channel Contention and Resource Management in Wireless Network

Field

Various embodiments described herein relate to the field of wireless communications and, particularly, to performing channel contention and resource
5 management.

Background

Some wireless networks employ channel contention. A device uses the channel contention to sense a radio channel for ongoing transmissions and ultimately to gain access to the radio channel. The channel access may be used to transmit data to
10 another device. The channel contention may follow principles of carrier sensing multiple access with collision avoidance (CSMA/CA) or another channel contention principle.

Radio resource management may be described as a policy for selecting transmission parameters for the device. Some radio resource management solutions
15 involve a centralized controller such as a base station selecting the transmission parameters for individual radio links.

Brief description

Some aspects of the invention are defined by the independent claims.

Some embodiments of the invention are defined in the dependent claims.

20 According to an aspect, there is provided an apparatus comprising means for performing: associating the apparatus to an access node of a wireless network; performing, during the association on a channel of the wireless network, channel contention for channel access separately for a plurality of parameter sets of the association, wherein the plurality of parameter sets comprise different combinations
25 of at least one transmission parameter and at least one access parameter, and wherein the at least one access parameter is used in the channel contention; winning the channel contention on a parameter set of the plurality of parameter sets and, thus, acquiring a transmission opportunity; and transmitting a frame during the transmission opportunity to the access node by using the at least one transmission
30 parameter of the parameter set.

In an embodiment, the at least one transmission parameter comprises transmission power.

In an embodiment, the means are configured to store, in association with each parameter set, a priority indicator indicating priority of said each parameter set

to channel access, and to select, upon winning the channel contention on the parameters set and also another parameter set of the plurality of parameter sets, for the transmission opportunity a parameter set that is associated with a priority indicator indicating higher priority to the channel access.

5 In an embodiment, the priority indicator is a transmission power value, and the means are configured to select for the transmission opportunity a parameter set that has the lower transmission power.

 In an embodiment, the priority indicator is activity rate defined as a relation between an expected channel contention duration and an expected duration of the
10 transmission opportunity, and wherein the means are configured to select for the transmission opportunity a parameter set having the higher activity rate.

 In an embodiment, the at least one access parameter comprises an energy detection threshold.

 In an embodiment, the wireless network is a wireless local area network.

15 In an embodiment, the means for performing the channel contention are configured to perform the channel contention simultaneously for the plurality of parameter sets.

 In an embodiment, the at least one transmission parameter comprises a receiver address for a data frame, and wherein at least two of the parameter sets
20 comprise different receiver addresses.

 In an embodiment, the means for performing the channel contention are configured to employ a backoff counter during the channel contention, and to employ separate backoff counters for the plurality of parameters sets during the channel contention.

25 In an embodiment, the means for performing the channel contention are configured to employ a backoff counter during the channel contention, and to employ a common backoff counter for the plurality of parameters sets during the channel contention, and further comprising means for selecting the transmission opportunity for one of the parameter sets upon winning the channel contention.

30 In an embodiment, the apparatus further comprises means for computing, on the basis measurements performed during the association, duration of a contention window to be used in the channel contention.

 In an embodiment, the means for computing are configured to compute the duration of the contention window separately for each parameter set on the basis of
35 measurements performed during one or more past transmission opportunities of said each parameter set.

In an embodiment, the channel is a frequency channel.

In an embodiment, the means comprises: at least one processor; and at least one memory including computer program code, the at least one memory and computer program code configured to, with the at least one processor, cause the performance of the apparatus.

According to another aspect, there is provided a method comprising: associating, by a wireless device, to an access node of a wireless network; performing, by the wireless device during the association on a channel of the wireless network, channel contention for channel access separately for a plurality of parameter sets of the association, wherein the plurality of parameter sets comprise different combinations of at least one transmission parameter and at least one access parameter, and wherein the at least one access parameter is used in the channel contention; winning, by the wireless device, the channel contention on a parameter set of the plurality of parameter sets and, thus, acquiring a transmission opportunity; and transmitting, by the wireless device, a frame during the transmission opportunity to the access node by using the at least one transmission parameter of the parameter set.

In an embodiment, the at least one transmission parameter comprises transmission power.

In an embodiment, the method further comprises: storing, in association with each parameter set, a priority indicator indicating priority of said each parameter set to channel access, and selecting, upon winning the channel contention on the parameters set and also another parameter set of the plurality of parameter sets, for the transmission opportunity a parameter set that is associated with a priority indicator indicating higher priority to the channel access.

In an embodiment, the priority indicator is a transmission power value, and a parameter set that has the lower transmission power is selected for the transmission opportunity.

In an embodiment, the priority indicator is an activity rate defined as a relation between an expected channel contention duration and an expected duration of the transmission opportunity, and wherein a parameter set having the higher activity rate is selected for the transmission opportunity.

In an embodiment, the at least one access parameter comprises an energy detection threshold.

In an embodiment, the wireless network is a wireless local area network.

In an embodiment, the channel contention is performed simultaneously for the plurality of parameter sets.

In an embodiment, the at least one transmission parameter comprises a receiver address for a data frame, and wherein at least two of the parameter sets comprise different receiver addresses.

In an embodiment, separate backoff counters are employed for the plurality
5 of parameters sets during the channel contention.

In an embodiment, a common backoff counter is employed for the plurality of parameters sets during the channel contention, and the transmission opportunity is selected for one of the parameter sets upon winning the channel contention.

In an embodiment, a duration of a contention window to be used in the
10 channel contention is computed on the basis measurements performed during the association.

In an embodiment, the duration of the contention window is computed separately for each parameter set on the basis of measurements performed during one or more past transmission opportunities of said each parameter set.

15 According to another aspect, there is provided a computer program product embodied on a distribution medium readable by a computer and comprising program instructions which, when read by the computer, cause the computer to execute a computer process comprising: associating a wireless device to an access node of a wireless network; performing, during the association on a channel of the wireless
20 network, channel contention for channel access separately for a plurality of parameter sets of the association, wherein the plurality of parameter sets comprise different combinations of at least one transmission parameter and at least one access parameter, and wherein the at least one access parameter is used in the channel contention; winning the channel contention on a parameter set of the plurality of parameter sets
25 and, thus, acquiring a transmission opportunity; and causing the wireless device to transmit a frame during the transmission opportunity to the access node by using the at least one transmission parameter of the parameter set.

List of drawings

30 Embodiments are described below, by way of example only, with reference to the accompanying drawings, in which

Figure 1 illustrates a wireless communication scenario to which some embodiments of the invention may be applied;

Figure 2 illustrates an embodiment of a process for determining
35 transmission parameters by using channel contention;

Figure 3 illustrates an embodiment of a scenario where a wireless device has multiple parameter sets having different combinations of at least one access parameter and at least one transmission parameter;

Figures 4 and 5 illustrates some embodiments for performing channel contention for multiple parameter sets;

Figure 6 and 7 illustrate embodiments for solving a parameter set to acquire a transmission opportunity amongst multiple parameter sets that won channel contention;

Figure 8 illustrates a procedure for determining or updating the parameter sets according to an embodiment; and

Figure 9 illustrate a block diagram of a structure of an apparatus according to an embodiment of the invention.

Description of embodiments

The following embodiments are examples. Although the specification may refer to “an”, “one”, or “some” embodiment(s) in several locations, this does not necessarily mean that each such reference is to the same embodiment(s), or that the feature only applies to a single embodiment. Single features of different embodiments may also be combined to provide other embodiments. Furthermore, words “comprising” and “including” should be understood as not limiting the described embodiments to consist of only those features that have been mentioned and such embodiments may contain also features/structures that have not been specifically mentioned.

A general wireless communication scenario to which embodiments of the invention may be applied is illustrated in Figure 1. Figure 1 illustrates wireless communication devices comprising a plurality of access points (AP) 102, 104 and a wireless terminal device (STA) 100. Each AP may be associated with a basic service set (BSS) which is a basic building block of an IEEE 802.11 wireless local area network (WLAN). The most common BSS type is an infrastructure BSS that includes a single AP together with all STAs associated with the AP. The AP may be a fixed AP or it may be a mobile AP. The APs 102, 104 may also provide access to other networks, e.g. the Internet 150. In another embodiment, the BSS may comprise a plurality of APs to form an extended service set (ESS), e.g. the APs 102, 104 may belong to the same ESS and have the same BSS identifier (BSSID). In the case of ESS, for example, the STA may have an association to multiple access nodes of the same ESS. While embodiments of the invention are described in the context of the above-described topologies of IEEE

802.11 based networks, it should be appreciated that these or other embodiments of the invention may be applicable to networks based on other specifications, e.g. different versions of the IEEE 802.11, WiMAX (Worldwide Interoperability for Microwave Access), UMTS LTE (Long-term Evolution for Universal Mobile Telecommunication System), and other networks having cognitive radio features, e.g. transmission medium sensing features and adaptiveness to coexist with radio access networks based on different specifications and/or standards. Other networks may allow the terminal device to have multiple associations to different access nodes of the same network. LTE and fifth generation (5G) cellular systems, for example, allow such multi-connectivity.

IEEE 802.11 specifications specify a data transmission mode that includes a primary channel and optionally secondary channels. The primary channel is used in all data transmissions and, in addition to the primary channel, one or more secondary channels may be employed for additional bandwidth. The transmission band of a BSS may contain the primary channel and zero or more secondary channels. The secondary channels may be used to increase data transfer capacity of a transmission opportunity (TXOP). The secondary channels may be called a secondary channel, a tertiary channel, a quaternary channel, etc. However, let us for the sake of simplicity use the secondary channel as the common term to refer also to the tertiary or quaternary channel, etc. The primary channel may be used for channel contention, and a TXOP may be gained after successful channel contention on the primary channel.

The TXOP may be defined as an interval of time during which a particular station has the right to initiate frame exchange sequences on at least one frequency channel. Other stations may not have rights to initiate frame exchange sequences during the interval of time. The frame exchange sequences comprise at least transmission of one or more frames and/or packets from the particular station to another station. The frame exchange sequences may comprise reception of at least acknowledgements from the other station.

In an embodiment, the primary channel and the secondary channels are frequency channels. The bandwidth of these frequency channels may be 20MHz. In other embodiments, the frequency bandwidth of these channels may be smaller or larger than 20MHz. The primary channel and the secondary channels may be non-overlapping in a frequency domain. The primary channel and at least one secondary channel may be contiguous or at least partly non-contiguous channels in the frequency domain.

Some IEEE 802.11 networks employ channel contention based on carrier sense multiple access with collision avoidance (CSMA/CA) for channel access. Every device attempting to gain a TXOP is reducing a backoff value while the primary channel is sensed to be idle for a certain time interval. The backoff value may be selected randomly within a range defined by a contention window parameter. The contention window may have different ranges for different types of traffic, thus affecting priority of the different types of traffic. The channel sensing may be based on sensing a level of radio energy in the radio channel. The sensed level may be compared with a threshold: if the sensed level is below the threshold level, the channel may be determined to be idle (otherwise busy). Such a procedure is called clear channel assessment (CCA) in 802.11 specifications. When the backoff value reaches zero, the STA gains the TXOP and starts frame transmission. If another STA gains the TXOP before that, the backoff value computation may be suspended, and the STA continues the backoff computation after the TXOP of the other STA has ended and the primary channel is sensed to be idle. The time duration (the backoff value) may not be decremented during the TXOP of the other STA, but the time duration that already lapsed before the suspension may be maintained, which means that the device now has a higher probability of gaining the TXOP. A secondary channel may be used in the transmission if it has been free for a determined time period (may be the same or different time period than that used for gaining the TXOP) just before TXOP start time in order for the contending device to take the secondary channel in use.

The STA 100 may be considered to be a terminal device or a station capable of connecting or associating to any one of the APs 102, 104. The STA may establish a connection with any one of APs it has detected to provide a wireless connection within the neighbourhood of the STA 100. The connection establishment may include authentication in which an identity of the STA is established in the AP. The authentication may comprise setting up an encryption key used in the BSS. After the authentication, the AP and the STA may carry out association in which the STA is fully registered in the BSS, e.g. by providing the STA with an association identifier (AID). A separate user authentication may follow association, which may also comprise building an encryption key used in the BSS. It should be noted that in other systems terms authentication and association are not necessarily used and, therefore, the association of the STA to an AP should be understood broadly as establishing a connection between the STA and the AP such that the STA is in a connected state with respect to the AP and waiting for downlink frame transmissions from the AP and monitoring its own buffers for uplink frame transmissions. A STA not associated to the AP is in an unassociated

state. An unassociated STA may still exchange some frames with the AP, e.g. discovery frames. In the associated state, the STA may in some embodiments operate occasionally in a power saving mode in which it is not monitoring downlink frame transmissions or uplink transmission buffers.

5 In some conventional wireless networks, radio resource management (RRM) is used to select transmission parameters for wireless devices with the aim of improving spectral efficiency and overall performance of a wireless network. In many wireless scenarios interference amongst devices of the same network and inter-system interference limits the performance. Some systems employ centralized RRM control,
10 e.g. in a network controller. Such solutions may, however, increase signaling overhead and complexity of the system.

Figure 2 illustrates an embodiment of a procedure for performing the RRM in connection with channel contention. The process may be executed in the STA 100 or, in general, any wireless device configured to contend for channel access. Referring
15 to Figure 2, the process comprises as performed by the wireless device: associating the wireless device to an access node of a wireless network (block 200); performing (block 202), during the association on a channel of the wireless network, channel contention for channel access separately for a plurality of parameter sets 210, 212 of the association, wherein the plurality of parameter sets 210, 212 comprise different
20 combinations of at least one transmission parameter and at least one access parameter, and wherein the at least one access parameter is used in the channel contention 202; winning (block 204) the channel contention on a parameter set of the plurality of parameter sets and, thus, acquiring a transmission opportunity; and transmitting (block 206 or 208) a frame during the transmission opportunity to the access node by
25 using the at least one transmission parameter of the parameter set.

In particular, if the channel contention is won in block 204 for the parameter set 210, the process may proceed to block 206 where at least one transmission parameter of the parameter set 210 is used in the frame transmission. Similarly, if the channel contention is won in block 204 for the parameter set 212, the
30 process may proceed to block 208 where at least one transmission parameter of the parameter set 212 is used in the frame transmission.

The embodiment of Figure 2 thus employs the parameter sets 210, 212 in both blocks 202 and 206/208. The access parameter(s) and the transmission parameter(s) of a parameter set 210, 212 may be linked to each other such that upon
35 winning the channel contention by using the access parameter(s) of the parameter set 210, 212, the wireless device is bound to use the transmission parameter(s) of the

parameter set 210, 212 in the transmission opportunity. In this manner, the channel contention may be bound to the transmission parameters available to the wireless device during the transmission opportunity and RRM be carried out by the wireless device by using the channel contention.

5 In an embodiment, block 202 comprises transmitting an association request to the access node and receiving an association response from the access node.

In an embodiment, the at least one transmission parameter comprises transmission power.

10 In an embodiment, the at least one transmission parameter comprises a modulation and coding scheme.

In an embodiment, the at least one transmission parameter comprises a beamforming configuration defining a spatial direction to which a major part of energy of a radio beam is directed.

15 In an embodiment, the at least one access parameter comprises an energy detection threshold. The energy detection threshold may be a CCA threshold.

In an embodiment, the at least one access parameter comprises a contention window (CW) length.

In an embodiment, the at least one access parameter comprises an inter-frame space (IFS) length of 802.11 specifications.

20 In an embodiment, the at least one access parameter comprises a backoff parameter, e.g. a value of a backoff counter.

In an embodiment, the channel is a frequency channel.

25 In an embodiment, the at least one transmission parameter comprises the transmission power and the at least one access parameter comprises the energy detection threshold. The energy detection threshold may be adapted to one another such that the transmission power and the energy detection threshold in the different parameter sets are inversely proportional to one another. For example, a sum of the transmission power and the energy detection threshold may be kept constant. Accordingly, if the parameter set 210 comprises a higher energy detection threshold
30 than the parameter set 212, the transmission power level is lower in the parameter set 210 than in the parameter set 212. Such relation may be used to improve fair sharing of the channel access amongst contending devices.

35 In an embodiment, the at least one transmission parameter comprises a receiver address, e.g. an identifier of one of the access nodes to which the wireless device has been associated in block 200. For example, in an 802.11 network a STA may be associated to multiple access nodes of the same service set and perform frame

transmissions to either or both access nodes during the association. In this embodiment, the channel contention may be used to determine the access node to which to perform the frame transmission.

Figure 3 illustrates the concept of the different parameter sets. In this embodiment, the STA 100 has two possible APs 102, 104 to which to transmit frames. Accordingly, the at least one transmission parameter comprises a receiver address for a data frame, and at least two of the parameter sets comprise different receiver addresses. Additionally, the STA may transmit by using four transmit power levels: the STA has transmit power levels TX_PW1, TX_PW2, and TX_PW3 available when transmitting a frame to the AP 104, and transmit power levels TX_PW3 and TX_PW4 when transmitting a frame to the AP 102. Each transmit power level may be bound to a certain energy detection or channel sensing threshold CH_TH, as described above and illustrated in Figure 3.

From a viewpoint, it may be understood that the STA has five virtual links with the APs 102, 104 and the STA performs the channel contention for each of the virtual links. Channel access parameter values may depend on the transmission parameters of the virtual link, as described above. Figures 4 and 5 illustrate some embodiments for carrying out the channel contention simultaneously for the multiple parameter sets (or virtual links). The channel contention may be performed simultaneously on the same radio resources, e.g. the same frequency channel. Referring to Figure 4, the wireless device performs the channel contention according to block 202 simultaneously for the multiple parameter sets 1 to 4. Each parameter set may have a unique set of channel access parameters and/or transmission parameters. A separate backoff counter may be used for each parameter set. The backoff counters may be randomized or in other manner realized such that at a given time instant different parameter sets are associated with different backoff counter values in the channel contention, thus reducing probability of collisions between two parameter sets. Different channel access parameters in the parameters sets 1 to 4 may also affect that the backoff counters are reduced at different rates. As described above, the backoff counter is reduced when the channel sensing indicates the channel to be idle for a parameter set. As illustrated in Figure 4, the backoff counter of parameter set 2 reduces to zero first and, thereafter, the wireless device may perform the frame transmission in the acquired TXOP 400. An IFS may be provided between the moment the backoff counter reaches zero and the TXOP 400 starts. Upon starting the TXOP, the channel contentions of the other parameter sets stop the reduction of the respective backoff counters for the duration of the TXOP, as illustrated in Figure 4.

In another embodiment, the wireless device may employ a common backoff counter for multiple parameter sets during the channel contention. A subset of the parameter sets may use one backoff counter while another subset uses another backoff counter, each subset comprising multiple parameter sets, or all parameter sets may use the same backoff counter. For example, those parameter sets using the same energy detection threshold may use the same backoff counter. Figure 5 illustrates an embodiment where the parameter sets 2 and 3 use the same backoff counter. Accordingly, when the backoff counter reaches zero, there is an opportunity for each parameter set to acquire the TXOP 400. The wireless device may resolve the winner of the channel contention according to a determined criterion.

In an embodiment, each parameter set may be associated with a priority indicator indicating the priority of the parameter set for the channel access. The priority indicator may be a static parameter stored in association with the parameter sets, or the priority indicator may be dynamic and recomputed and updated repeatedly during the association. Upon multiple parameter sets winning the contention, the wireless device may check the priority indicators of the parameter sets that won the contention and allocate the TXOP to the parameter set having the priority indicator indicating the highest priority amongst the winning parameter sets. Figures 6 and 7 illustrate some embodiments for resolving the winning parameter set by using different priority indicators. In the embodiment of Figure 6, the priority indicator is dynamic and taking the form of an activity rate. In the embodiment of Figure 7, the priority indicator is static and takes the form of transmission power level. Let us first, however, define some factors that may be used in the embodiments described herein.

Let us define an expected value of a channel contention time for a parameter set i as $E(C_i)$, and an expected value of a TXOP duration for the parameter set i as $E(T_i)$, respectively. The expected values may have a relation on statistical expected values observed during the association of the wireless device. The principles below have a background in continuous time Markov chains used in the literature to model networks using CSMA/CA as the channel contention mechanism.

Let us make the following assumptions: TXOP durations of any parameter set i are distributed with mean $E(T_i)$; contention times for any parameter set i are also distributed with mean $E(C_i)$. Let us then define an activity rate a_i for any parameter set i $a_i = E(T_i) / E(C_i)$. Then, we obtain the following long-term fraction f_M of time that exactly a subset of parameter sets M is transmitting as

$$f_M = k \prod_{i \in M} a_i, \quad (1)$$

where k is a constant scaling factor that may be used to ensure that the sum of all fractions is one. A total time a single parameter set i is transmitting may be obtained by summing together the fractions f_M to which the parameter set i belongs. When the parameter sets contend with each other, as described above, we obtain that $E(T_i)$ is the
 5 expected length of a TXOP and $E(C_i)=CW_i/2$, where CW_i is a contention window of the backoff of link i . Let us then define utility u_i for a parameter set realized when the parameter set is transmitting and define the activity rate through the utility as:

$$a_i = b^{u_i} \quad (2)$$

where b is a constant. Then, we can modify Equation (1) into the following form:

$$f_M = kb \sum_{i \in M} u_i. \quad (3)$$

When considering the continuous time Markov chains on a network level with multiple contending wireless devices, a model may be constructed where a certain parameter set of a wireless device, upon gaining the TXOP, blocks channel access for one or more other parameter sets of the wireless device and other wireless devices. If
 15 every wireless device used the same channel access parameters so that u_i for every link i would be equal, we would obtain that the wireless network nearly maximizes the average number of simultaneous transmitters.

The activity rate a_i may be used in solving the parameter set to acquire the TXOP when the multiple parameter sets win the channel contention. Figure 6
 20 illustrates an embodiment for performing the selection of the parameter set. Referring to Figure 6, the wireless device may perform the channel contention simultaneously for the multiple parameter sets in block 600, e.g. by using the common backoff counter. Upon winning the channel contention when a backoff counter is reduced to zero, the wireless device may determine (block 602) whether the channel contention was won on
 25 multiple parameter sets. If only one parameter set won the channel contention, the process may proceed to block 608 where the parameter set acquires the TXOP, and the frame transmission is performed by using transmission parameters of the parameter set.

If the channel contention was won on multiple parameter sets, the process
 30 may proceed to block 604 where activity rates a_i are computed for each parameter set. The wireless device may measure the activity rate a_i for each parameter set by measuring an average TXOP duration and an average channel contention time for each parameter set and computing their mutual relation, e.g. ratio. The channel contention time may be computed as a total time interval from start of channel contention with a
 35 maximum value of the backoff counter to the moment when the backoff counter is

reduced to zero. In another embodiment, also IFS periods are also computed to the channel contention time. For example, the backoff counter reduction is started only upon detecting the channel to be idle for a time interval defined by arbitration IFS (AIFS). The AIFS period may be computed to the channel contention time. In block 604, the readily computed activity rates may be retrieved from a memory and, in block 606, the parameter set having the highest activity rate is selected to acquire the TXOP, and the frame may be transmitted by using the selected parameter set in block 608.

The embodiment of Figure 6 prefers parameter sets having a high activity rate. Figure 7 illustrates an embodiment that prefers reduced transmission power to reduce interference and to improve the probability for a high number of simultaneous users on the same channel, e.g. a frequency channel. In Figure 7, the blocks denoted by the same reference numbers as in Figure 6 represent the same or substantially similar functions. Referring to Figure 7, upon multiple parameter sets winning the channel contention the wireless device may determine the transmission power parameters of the multiple parameter sets in block 700. Then, the wireless device may select the parameter set having the lowest transmission power parameter. In this manner, the wireless device may prefer those parameter sets that are used to transmit the frame with a low transmission power level.

In an embodiment, the wireless device computes a duration of a contention window to be used in the channel contention. The computation may employ as an input measurements performed during the association. Figure 8 illustrates an embodiment of such a process that may be executed during the association and before carrying out one of the channel contentions the wireless device performs in block 202 or 600. Referring to Figure 8, the wireless device may measure the some characteristics for a parameter set in block 800. The measured characteristics may include throughput t_i . The throughput may be estimated by using Shannon-Hartley theorem as:

$$t_i = B \log_2 \left(\frac{S}{I} \right), \quad (4)$$

where B is the bandwidth, S is a signal strength of a signal measured at a receiver of a frame, and I represents interference level. The wireless device may measure the S/I from a reference signal received from the access node, from any signal detected in the radio channel, or by using other state-of-the-art solutions, and the bandwidth may be a transmission bandwidth supported by the wireless device. In another embodiment, the wireless device may measure the real throughput in bits per second when transmitting with the parameter set under study. Now, the utility may be defined for

uplink UL and downlink DL by using the measured throughput and a maximum throughput t_{max} for a wireless device c as follows:

$$u_i = \frac{t_i}{t_{max,UL}(c)}. \quad (5)$$

$$u_i = \frac{t_i}{t_{max,DL}(c)}. \quad (6)$$

- 5 The utility using the relation of the observed throughput with the maximum throughput improve fairness amongst wireless devices.

Let us make an assumption that the TXOP duration T_{TXOP} assumes the maximum value of the TXOP duration. This would be the case when the wireless device has a transmit buffer so full of data that the maximum TXOP duration will be utilized.

- 10 In another embodiment, the TXOP durations of the parameter set may be measured (block 800) and an average TXOP duration may be used instead. Then, the length of the contention window CW_i may be computed in block 802 as:

$$CW_i = \left\lceil \frac{2T_{TXOP}}{b^{u_i}} \right\rceil = \left\lceil 2T_{TXOP} \left(\frac{2T_{TXOP}}{\min CW} \right)^{-\frac{t_i}{t_{max,DL}}} \right\rceil. \quad (7)$$

- 15 CW_{min} is the minimum contention window size. Equation (7) is the contention window for downlink but the Equation is equally valid for uplink, only the exponent is acquired from Equation (5) instead of Equation (6). The contention window thus computed may then be input to the parameter set as an access parameter (block 804).

- 20 The duration of the contention window may be computed separately for each parameter set on the basis of measurements performed during one or more past transmission opportunities of said each parameter set. Accordingly, the process of Figure 8 may determine in block 806 whether or not to update or generate the contention window size for the next parameter set. If yes, the process returns to block 800 to acquire the measurements for the next parameter set. Otherwise, the process may end.

- 25 The process of Figure 8 may be executed periodically or on a need basis. It may be executed in parallel with the process of Figure 2, 6 or 7.

- 30 Figure 9 illustrates an embodiment of a structure of the above-mentioned functionalities of an apparatus executing the functions of the wireless device in the process of Figure 2 or any one of the embodiment described above for the wireless device. The apparatus may be a terminal device or a client device of a wireless network, e.g. the 802.11 network. In other embodiments, the apparatus may be a circuitry or an

electronic device realizing some embodiments of the invention in the wireless device. The apparatus may comply with 802.11 specifications. The apparatus may be or may be comprised in a computer (PC), a laptop, a tablet computer, a cellular phone, a palm computer, a sensor device, or any other apparatus provided with radio communication capability. In another embodiment, the apparatus carrying out the above-described functionalities is comprised in such a device, e.g. the apparatus may comprise a circuitry such as a chip, a chipset, a processor, a micro controller, or a combination of such circuitries in any one of the above-described devices. The apparatus may be an electronic device comprising electronic circuitries for realizing some embodiments of the present invention.

Referring to Figure 9, the apparatus may comprise a station entity 50 providing the apparatus with capability of communicating in the wireless network of the access node. The station entity may comprise a radio interface 22 providing the apparatus with radio communication capability. The radio interface 22 may comprise radio frequency converters and components such as an amplifier, filter, frequency-converter, (de)modulator, and encoder/decoder circuitries and one or more antennas. The station entity 50 may further comprise a radio modem 58 configured to carry out transmission and reception of messages in the wireless network. The station entity may further comprise one or more contention engines 52 to 56, depending on the implementation. In the embodiments where the channel contention is performed separately for multiple parameter sets, the station entity may comprise multiple contention engines, one per parameter set. An embodiment using the common contention engine may comprise only one contention engine. The contention engines may acquire the TXOP for the apparatus and, thus, control the channel access of the radio modem 58 in the above-described manner.

The station entity may further comprise a RRM manager 55 configured to manage the parameters of the parameter sets. The RRM manager may, for example update the access parameters and/or the transmission parameters of the parameter sets in the above-described manner.

The station entity may comprise at least one processor comprising the RRM manager 55 and the contention engine(s) 52 to 56 and comprising or controlling the operation of the radio modem 58.

The apparatus may further comprise an application processor 56 executing one or more computer program applications that generate a need to transmit and/or receive data through the station entity 50. The application processor may form an application layer of the apparatus. The application processor may execute computer

programs forming the primary function of the apparatus. For example, if the apparatus is a sensor device, the application processor may execute one or more signal processing applications processing measurement data acquired from one or more sensor heads. If the apparatus is a computer system of a vehicle, the application processor may execute
5 a media application and/or an autonomous driving and navigation application. The application processor may generate data to be transmitted in the wireless network.

The apparatus may further comprise a memory 60 storing one or more computer program products 62 configuring the operation of said processor(s) of the apparatus. The memory 60 may further store a configuration database 64 storing
10 operational configurations of the apparatus. The configuration database 64 may, for example, store the parameter sets and definitions for the transmission parameter(s) and access parameter(s) of each parameter set. The RRM manager 55 may update the parameter sets in the above-described manner.

As used in this application, the term 'circuitry' refers to one or more of the
15 following: (a) hardware-only circuit implementations such as implementations in only analog and/or digital circuitry; (b) combinations of circuits and software and/or firmware, such as (as applicable): (i) a combination of processor(s) or processor cores; or (ii) portions of processor(s)/software including digital signal processor(s), software, and at least one memory that work together to cause an apparatus to perform
20 specific functions; and (c) circuits, such as a microprocessor(s) or a portion of a microprocessor(s), that require software or firmware for operation, even if the software or firmware is not physically present.

This definition of 'circuitry' applies to uses of this term in this application. As a further example, as used in this application, the term "circuitry" would also cover
25 an implementation of merely a processor (or multiple processors) or portion of a processor, e.g. one core of a multi-core processor, and its (or their) accompanying software and/or firmware. The term "circuitry" would also cover, for example and if applicable to the particular element, a baseband integrated circuit, an application-specific integrated circuit (ASIC), and/or a field-programmable grid array (FPGA)
30 circuit for the apparatus according to an embodiment of the invention.

The processes or methods described in Figures 2 to 8 may also be carried out in the form of one or more computer processes defined by one or more computer programs. A separate computer program may be provided in one or more apparatuses that execute functions of the processes described in connection with the Figures. The
35 computer program(s) may be in source code form, object code form, or in some intermediate form, and it may be stored in some sort of carrier, which may be any entity

or device capable of carrying the program. Such carriers include transitory and/or non-transitory computer media, e.g. a record medium, computer memory, read-only memory, electrical carrier signal, telecommunications signal, and software distribution package. Depending on the processing power needed, the computer program may be
5 executed in a single electronic digital processing unit or it may be distributed amongst a number of processing units.

Embodiments described herein are applicable to wireless networks defined above but also to other wireless networks. The protocols used, the specifications of the wireless networks and their network elements develop rapidly. Such development may
10 require extra changes to the described embodiments. Therefore, all words and expressions should be interpreted broadly and they are intended to illustrate, not to restrict, the embodiment. It will be obvious to a person skilled in the art that, as technology advances, the inventive concept can be implemented in various ways. Embodiments are not limited to the examples described above but may vary within the
15 scope of the claims.

Claims

1. An apparatus comprising means for performing:
associating the apparatus to an access node of a wireless network;

5 performing, during the association on a channel of the wireless network, channel
contention for channel access separately for a plurality of parameter sets of the
association, wherein the plurality of parameter sets comprise different
combinations of at least one transmission parameter and at least one access
parameter, and wherein the at least one access parameter is used in the channel
10 contention;

winning the channel contention on a parameter set of the plurality of parameter
sets and, thus, acquiring a transmission opportunity; and

15 transmitting a frame during the transmission opportunity to the access node by
using the at least one transmission parameter of the parameter set.
2. The apparatus of claim 1, wherein the at least one transmission parameter
comprises transmission power.
20
3. The apparatus of claim 1 or 2, wherein the means are configured to store, in
association with each parameter set, a priority indicator indicating priority of said
each parameter set to channel access, and to select, upon winning the channel
contention on the parameters set and also another parameter set of the plurality
25 of parameter sets, for the transmission opportunity a parameter set that is
associated with a priority indicator indicating higher priority to the channel access.
4. The apparatus of claim 3, wherein the priority indicator is a transmission power
value, and the means are configured to select for the transmission opportunity a
30 parameter set that has the lower transmission power.
5. The apparatus of claim 3, wherein the priority indicator is activity rate defined as
a relation between an expected channel contention duration and an expected
duration of the transmission opportunity, and wherein the means are configured
35 to select for the transmission opportunity a parameter set having the higher

activity rate.

6. The apparatus of any preceding claim, wherein the at least one access parameter comprises an energy detection threshold.

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7. The apparatus of any preceding claim, wherein the wireless network is a wireless local area network.

8. The apparatus of any preceding claim, wherein the means for performing the channel contention are configured to perform the channel contention simultaneously for the plurality of parameter sets.

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9. The apparatus of any preceding claim, wherein the at least one transmission parameter comprises a receiver address for a data frame, and wherein at least two of the parameter sets comprise different receiver addresses.

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10. The apparatus of any preceding claim, wherein the means for performing the channel contention are configured to employ a backoff counter during the channel contention, and to employ separate backoff counters for the plurality of parameters sets during the channel contention.

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11. The apparatus of any preceding claim 1 to 9, wherein the means for performing the channel contention are configured to employ a backoff counter during the channel contention, and to employ a common backoff counter for the plurality of parameters sets during the channel contention, and further comprising means for selecting the transmission opportunity for one of the parameter sets upon winning the channel contention.

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12. The apparatus of any preceding claim, further comprising means for computing, on the basis measurements performed during the association, duration of a contention window to be used in the channel contention.

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13. The apparatus of claim 12, wherein the means for computing are configured to compute the duration of the contention window separately for each parameter set on the basis of measurements performed during one or more past transmission

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opportunities of said each parameter set.

14. The apparatus of any preceding claim, wherein the channel is a frequency channel.

5 15. The apparatus of any preceding claim, wherein the means comprises:
at least one processor; and
at least one memory including computer program code, the at least one
memory and computer program code configured to, with the at least one processor,
cause the performance of the apparatus.

10

16. A method comprising:
associating, by a wireless device, to an access node of a wireless network;

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performing, by the wireless device during the association on a channel of the
wireless network, channel contention for channel access separately for a plurality
of parameter sets of the association, wherein the plurality of parameter sets
comprise different combinations of at least one transmission parameter and at
least one access parameter, and wherein the at least one access parameter is used
in the channel contention;

20

winning, by the wireless device, the channel contention on a parameter set of the
plurality of parameter sets and, thus, acquiring a transmission opportunity; and

25

transmitting, by the wireless device, a frame during the transmission opportunity
to the access node by using the at least one transmission parameter of the
parameter set.

17. The method of claim 16, wherein the at least one transmission parameter
comprises transmission power.

30

18. The method of claim 16 or 17, further comprising:

storing, in association with each parameter set, a priority indicator indicating
priority of said each parameter set to channel access, and

35

selecting, upon winning the channel contention on the parameters set and also

another parameter set of the plurality of parameter sets, for the transmission opportunity a parameter set that is associated with a priority indicator indicating higher priority to the channel access.

- 5 19. The method of claim 18, wherein the priority indicator is a transmission power value, and a parameter set that has the lower transmission power is selected for the transmission opportunity.
- 10 20. The method of claim 18, wherein priority indicator is activity rate defined as a relation between an expected channel contention duration and an expected duration of the transmission opportunity, and wherein a parameter set having the higher activity rate is selected for the transmission opportunity.
- 15 21. The method of any preceding claim 16 to 20, wherein the at least one access parameter comprises an energy detection threshold.
22. The method of any preceding claim 16 to 21, wherein the wireless network is a wireless local area network.
- 20 23. The method of any preceding claim 16 to 22, wherein the channel contention is performed simultaneously for the plurality of parameter sets.
- 25 24. The method of any preceding claim 16 to 23, wherein the at least one transmission parameter comprises a receiver address for a data frame, and wherein at least two of the parameter sets comprise different receiver addresses.
25. The method of any preceding claim 16 to 24, wherein separate backoff counters are employed for the plurality of parameters sets during the channel contention.
- 30 26. The method of any preceding claim 16 to 24, wherein a common backoff counter is employed for the plurality of parameters sets during the channel contention, and the transmission opportunity is selected for one of the parameter sets upon winning the channel contention.
- 35 27. The method of any preceding claim 16 to 26, wherein a duration of a contention window to be used in the channel contention is computed on the basis

measurements performed during the association.

28. The method of claim 27, wherein the duration of the contention window is computed separately for each parameter set on the basis of measurements performed during one or more past transmission opportunities of said each parameter set.

29. A computer program product embodied on a distribution medium readable by a computer and comprising program instructions which, when read by the computer, cause the computer to execute a computer process comprising:

associating a wireless device to an access node of a wireless network;

performing, during the association on a channel of the wireless network, channel contention for channel access separately for a plurality of parameter sets of the association, wherein the plurality of parameter sets comprise different combinations of at least one transmission parameter and at least one access parameter, and wherein the at least one access parameter is used in the channel contention;

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winning the channel contention on a parameter set of the plurality of parameter sets and, thus, acquiring a transmission opportunity; and

causing the wireless device to transmit a frame during the transmission opportunity to the access node by using the at least one transmission parameter of the parameter set.

25

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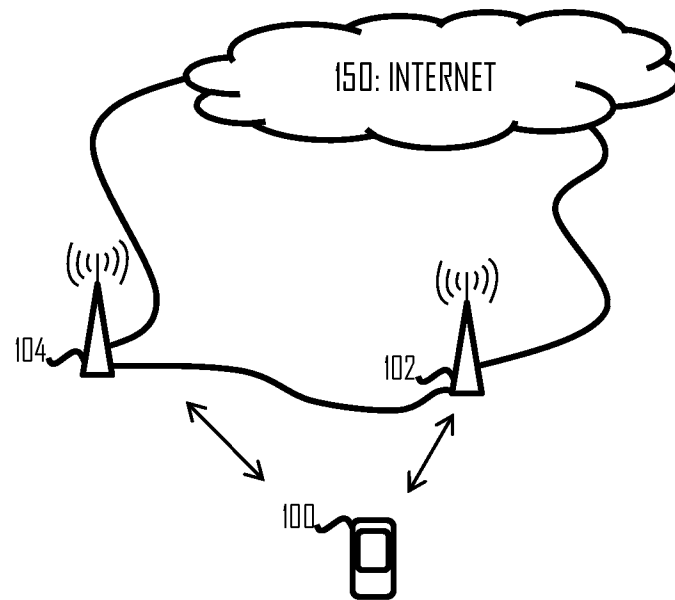


Fig 1

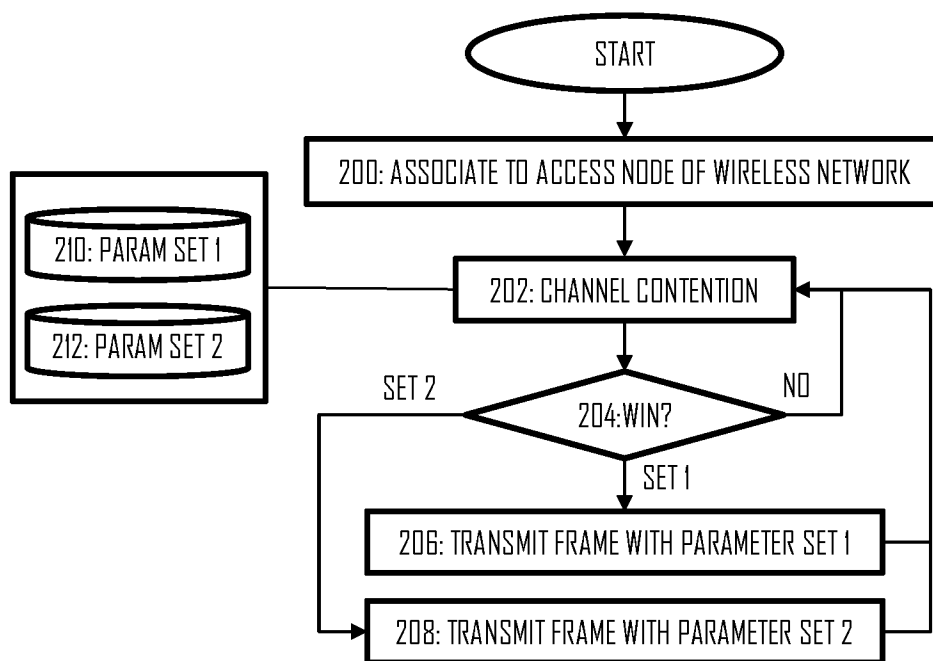
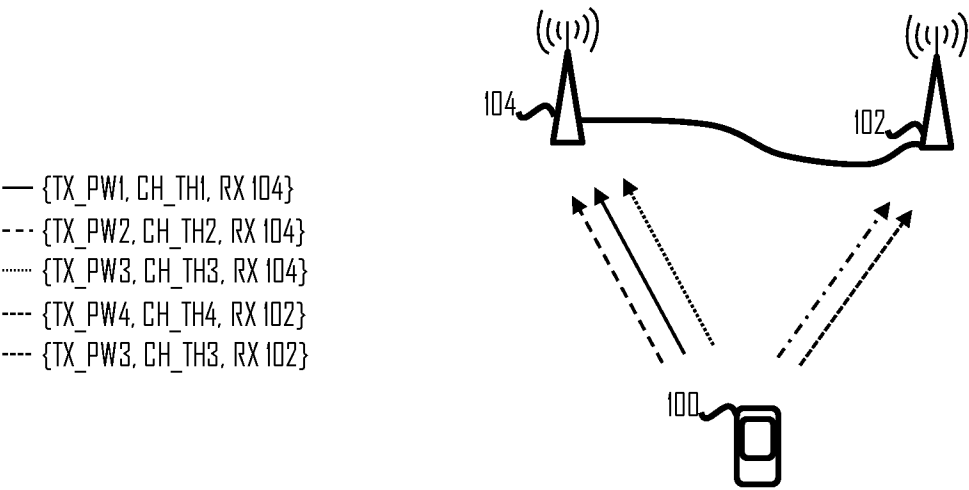


Fig 2



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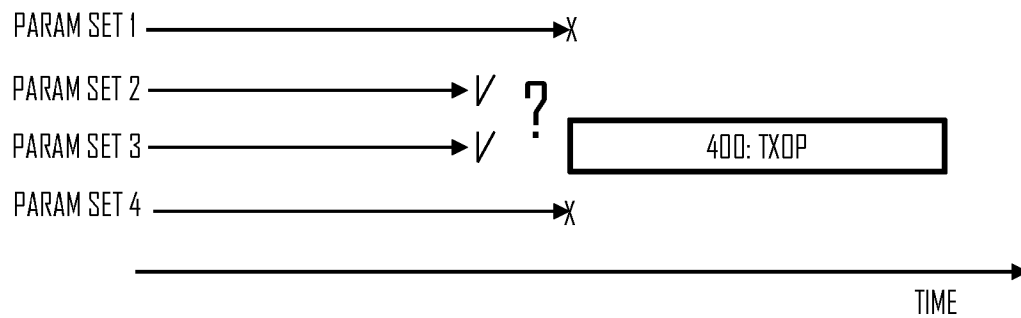


Fig 5

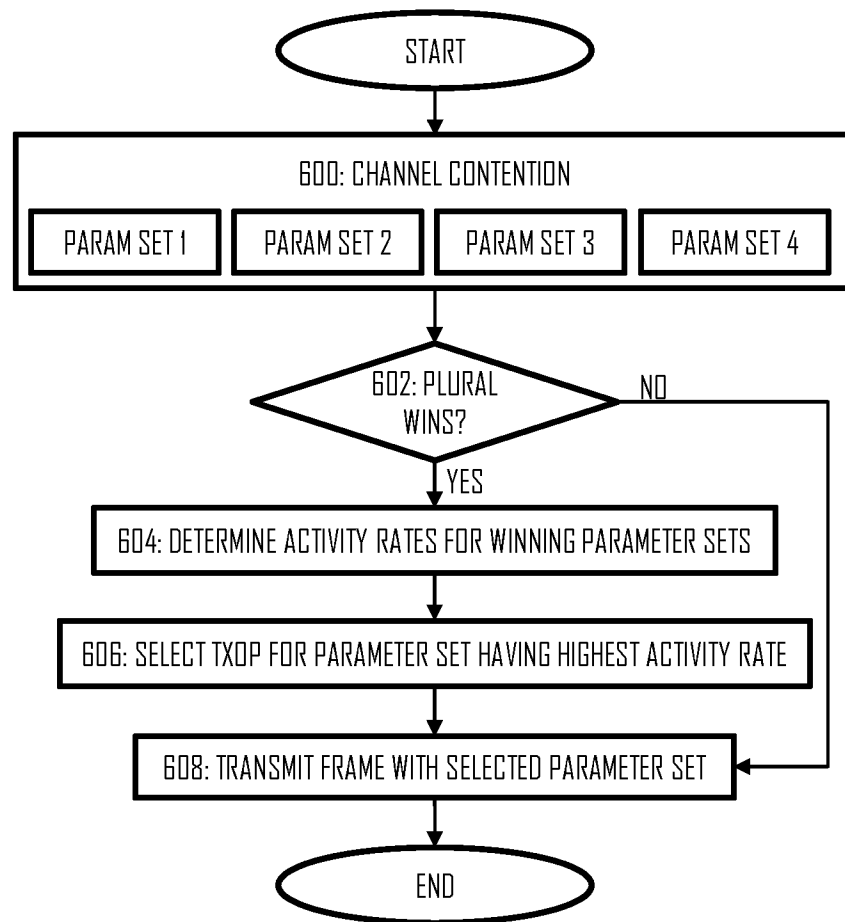


Fig 6

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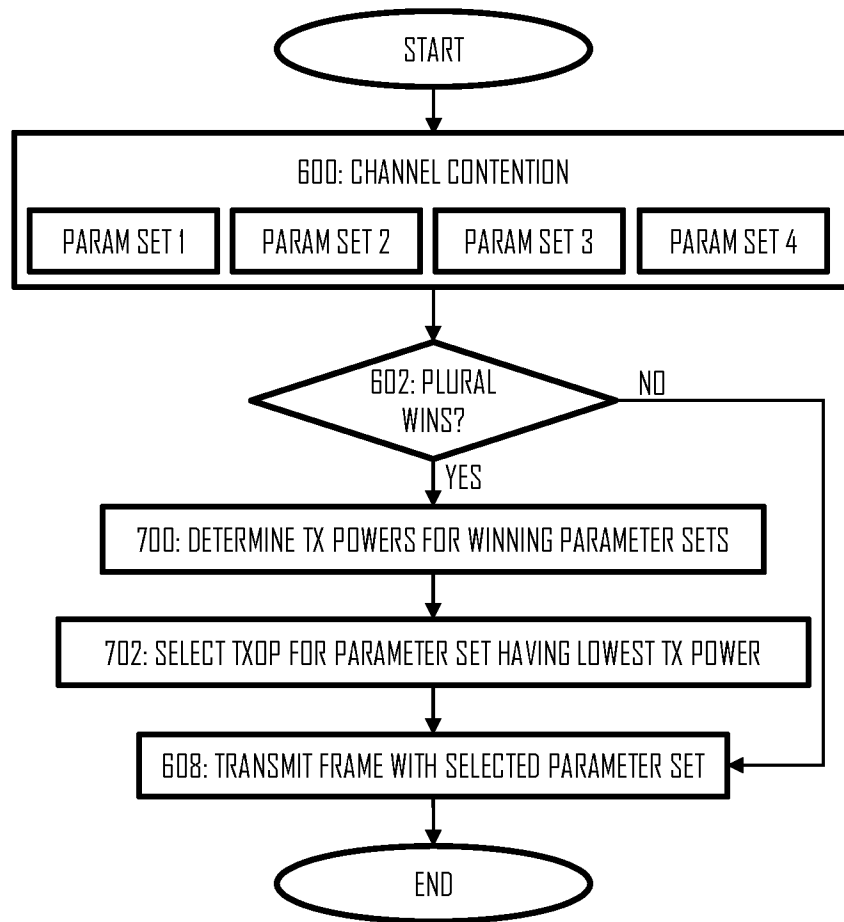


Fig 7

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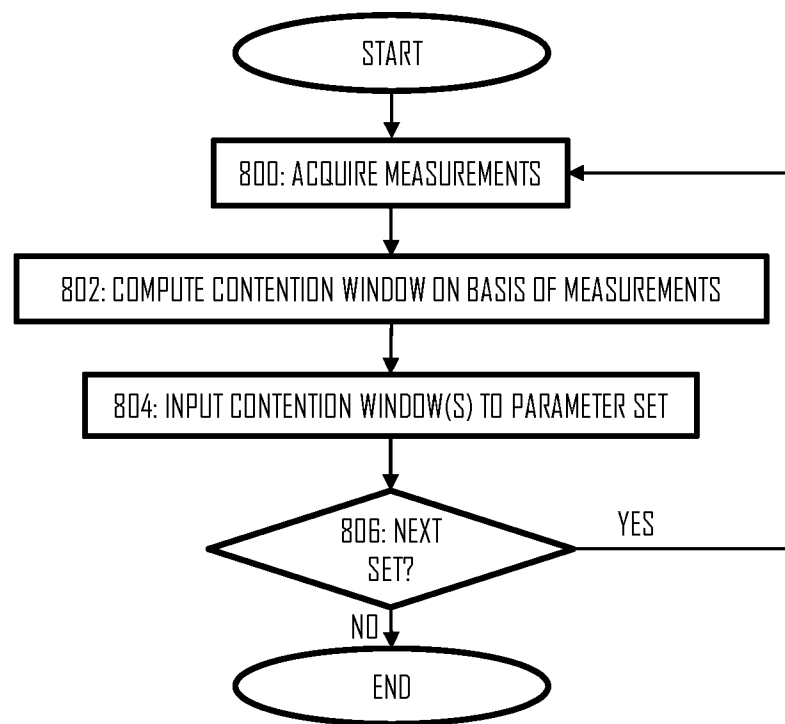


Fig 8

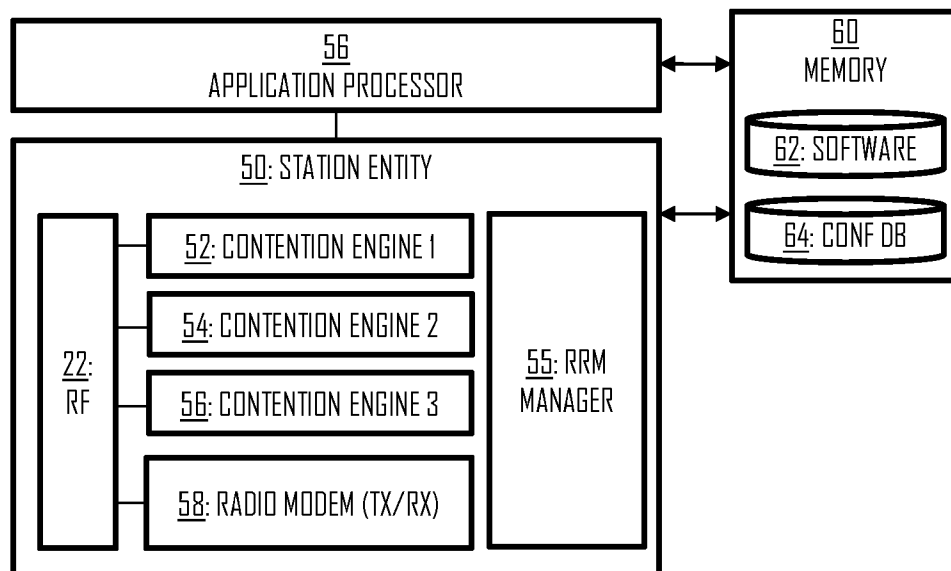


Fig 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/FI2018/050865

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W74/08
ADD.

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

B. FIELDS SEARCHED

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

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

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

EP0-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2017/050282 A1 (ZTE CORP [CN]) 30 March 2017 (2017-03-30) figure 1 & US 2019/014596 A1 (YANG LING [CN] ET AL) 10 January 2019 (2019-01-10) paragraphs [0124] - [0150], [0168], [0169], [0190] - [0194] -----	1-29
A	US 2015/319704 A1 (BAKER MATTHEW P J [GB] ET AL) 5 November 2015 (2015-11-05) claim 1 -----	1-29
A	US 2016/128070 A1 (HANUSCH THOMAS [DE] ET AL) 5 May 2016 (2016-05-05) paragraph [0079] ----- -/--	1-29



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

13 June 2019

Date of mailing of the international search report

24/06/2019

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

International application No
PCT/FI2018/050865

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2016/345326 A1 (YERRAMALLI SRINIVAS [US] ET AL) 24 November 2016 (2016-11-24) paragraph [0007]	1-29
A	----- US 2017/257852 A1 (WU CHIH-HSIANG [TW]) 7 September 2017 (2017-09-07) paragraphs [0041] - [0042] -----	1-29

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/FI2018/050865

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2017050282 A1	30-03-2017	CN 106559882 A US 2019014596 A1 WO 2017050282 A1	05-04-2017 10-01-2019 30-03-2017
US 2015319704 A1	05-11-2015	AT 510434 T CN 101843152 A EP 2218288 A1 ES 2366770 T3 JP 5710973 B2 JP 2011503951 A KR 20100103485 A TW 200939660 A US 2010302934 A1 US 2013044715 A1 US 2015319704 A1 WO 2009057043 A1	15-06-2011 22-09-2010 18-08-2010 25-10-2011 30-04-2015 27-01-2011 27-09-2010 16-09-2009 02-12-2010 21-02-2013 05-11-2015 07-05-2009
US 2016128070 A1	05-05-2016	DE 102015221473 A1 US 2016128070 A1	04-05-2016 05-05-2016
US 2016345326 A1	24-11-2016	BR 112017025060 A2 CA 2983110 A1 CN 107660344 A EP 3305005 A1 JP 2018520570 A KR 20180011106 A TW 201644220 A US 2016345326 A1 WO 2016191102 A1	07-08-2018 01-12-2016 02-02-2018 11-04-2018 26-07-2018 31-01-2018 16-12-2016 24-11-2016 01-12-2016
US 2017257852 A1	07-09-2017	CN 107155188 A EP 3214791 A2 EP 3276866 A1 EP 3276867 A1 US 2017257852 A1	12-09-2017 06-09-2017 31-01-2018 31-01-2018 07-09-2017