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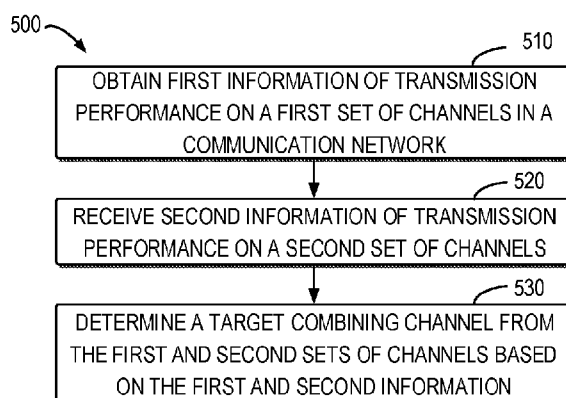


FIG. 5

(57) Abstract: Embodiments of the disclosure provide a method, device and computer readable medium for channel combination. According to embodiments of the present disclosure, the device determines the target combined channel based on performance information of the channels and the devices in the network. The target combined channel is determined based on dynamic performance of the channels. In this way, the best channel combination is selected and sensitivity to thresholds for detecting problems in the network is avoided.



METHOD, DEVICE AND COMPUTER READABLE MEDIUM FOR CHANNEL COMBINATION

FIELD

- 5 [0001] Embodiments of the present disclosure generally relate to communication techniques, and more particularly, to methods, devices and computer readable medium for channel combination.

BACKGROUND

- 10 [0002] In a communication network, several technologies of improving capacity have been proposed. For example, in a Wireless Mesh Networks (WMN) network, the devices operate on unlicensed spectrums at 2.4 and 5 GHz. Dense and non-coordinated IEEE 802.11 (Wi-Fi) deployments increase interference (hidden nodes) and/or contention (exposed nodes) that dramatically deteriorates the end user throughput
15 and increase the packet delay what is critical for delay sensitive services.

SUMMARY

- [0003] Generally, embodiments of the present disclosure relate to a method for channel combination and the corresponding communication devices.
- 20 [0004] In a first aspect, embodiments of the disclosure provide a device. The device comprises: at least one processor; and a memory coupled to the at least one processor, the memory storing instructions therein, the instructions, when executed by the at least one processor, causing the device to: obtain, at the device, first information of transmission performance on a first set of channels in a communication network. The device is
25 further caused to receive, at the device and from a further device in the communication network, second information of transmission performance on a second set of channels. The network device is also caused to determine a target combined channel from the first and second sets of channels based on the first and second information.
- [0005] In a second aspect, embodiments of the present disclosure provide a method.
30 The method comprises: obtaining, at a first device, first information of transmission performance on a first set of channels in a communication network. The method also

comprises receiving, at the first device and from a second device in the communication network, second information of transmission performance on a second set of channels. The method further comprises determine a target combined channels from the first and second sets of channels based on the first and second information.

5 [0006] In a third aspect, embodiments of the disclosure provide an apparatus. The apparatus comprises means for obtaining, at the apparatus, first information of transmission performance on a first set of channels in a communication network. The apparatus further comprises means for receiving, at the apparatus and from a further apparatus in the communication network, second information of transmission
10 performance on a second set of channels. The apparatus also comprises means for determining a target combined channels from the first and second sets of channels based on the first and second information.

[0007] In a fourth aspect, embodiments of the disclosure provide a computer readable medium. The computer readable medium stores instructions thereon, the instructions,
15 when executed by at least one processing unit of a machine, causing the machine to implement the methods according to the second aspect.

[0008] Other features and advantages of the embodiments of the present disclosure will also be apparent from the following description of specific embodiments when read in conjunction with the accompanying drawings, which illustrate, by way of example, the
20 principles of embodiments of the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Embodiments of the disclosure are presented in the sense of examples and their advantages are explained in greater detail below, with reference to the accompanying
25 drawings, where

[0010] Fig. 1 illustrates a schematic diagram of spectrum allocation in WiFi systems according to conventional technologies;

[0011] Fig. 2 illustrates a schematic diagram of spectrum optimization according to conventional technologies;

30 [0012] Fig. 3 illustrates a schematic diagram of performances of spectrum optimization

according to conventional technologies;

[0013] Fig. 4 illustrate a schematic diagrams of transmission communication system according to embodiments of the present disclosure;

5 [0014] Fig. 5 illustrates a flow chart of a method implemented at a communication device according to embodiments of the present disclosure;

[0015] Fig. 6 illustrates a flow chart of a method implemented at a communication device according to embodiments of the present disclosure;

[0016] Fig. 7 illustrates a schematic diagram of a device according to embodiments of the present disclosure; and

10 [0017] Fig. 8 shows a block diagram of an example computer readable medium in accordance with some embodiments of the present disclosure.

[0018] Throughout the figures, same or similar reference numbers indicate same or similar elements.

15 DETAILED DESCRIPTION OF EMBODIMENTS

[0019] The subject matter described herein will now be discussed with reference to several example embodiments. It should be understood these embodiments are discussed only for the purpose of enabling those skilled persons in the art to better understand and thus implement the subject matter described herein, rather than
20 suggesting any limitations on the scope of the subject matter.

[0020] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of example embodiments. As used herein, the singular forms “a,” “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further
25 understood that the terms “comprises,” “comprising,” “includes” and/or “including,” when used herein, specify the presence of stated features, integers, steps, operations, elements and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components and/or groups thereof.

30 [0021] It should also be noted that in some alternative implementations, the

functions/acts noted may occur out of the order noted in the figures. For example, two functions or acts shown in succession may in fact be executed concurrently or may sometimes be executed in the reverse order, depending upon the functionality/acts involved.

5 [0022] As used herein, the term “communication network” refers to a network following any suitable communication standards, such as Long Term Evolution (LTE), LTE-Advanced (LTE-A), Wideband Code Division Multiple Access (WCDMA), High-Speed Packet Access (HSPA), and so on. Furthermore, the communications between a terminal device and a network device in the communication network may be performed according to any suitable generation communication protocols, including, but
10 not limited to, the first generation (1G), the second generation (2G), 2.5G, 2.75G, the third generation (3G), the fourth generation (4G), 4.5G, the future fifth generation (5G) communication protocols, and/or any other protocols either currently known or to be developed in the future.

15 [0023] Embodiments of the present disclosure may be applied in various communication systems. Given the rapid development in communications, there will of course also be future type communication technologies and systems with which the present disclosure may be embodied. It should not be seen as limiting the scope of the present disclosure to only the aforementioned system. For the purpose of illustrations,
20 embodiments of the present disclosure will be described with reference to 5G communication system.

[0024] The term “network device” used herein includes, but not limited to, a base station (BS), a gateway, a registration management entity, and other suitable device in a communication system. The term “base station” or “BS” represents a node B (NodeB
25 or NB), an evolved NodeB (eNodeB or eNB), a NR NB (also referred to as a gNB), a Remote Radio Unit (RRU), a radio header (RH), a remote radio head (RRH), a relay, a low power node such as a femto, a pico, and so forth.

[0025] The term “terminal device” used herein includes, but not limited to, “user equipment (UE)” and other suitable end device capable of communicating with the
30 network device. By way of example, the “terminal device” may refer to a terminal, a Mobile Terminal (MT), a Subscriber Station (SS), a Portable Subscriber Station, a

Mobile Station (MS), or an Access Terminal (AT).

[0026] The term “circuitry” used herein may refer to one or more or all of the following:

5 [0027] (a) hardware-only circuit implementations (such as implementations in only analog and/or digital circuitry) and

[0028] (b) combinations of hardware circuits and software, such as (as applicable):

[0029] (i) a combination of analog and/or digital hardware circuit(s) with

[0030] software/firmware and

10 [0031] (ii) any portions of hardware processor(s) with software (including digital signal processor(s)), software, and memory(ies) that work together to cause an apparatus, such as a mobile phone or server, to perform various functions) and

[0032] (c) hardware circuit(s) and or processor(s), such as a microprocessor(s) or a portion of a microprocessor(s), that requires software (e.g., firmware) for operation, but the software may not be present when it is not needed for operation.”

15 [0033] This definition of circuitry applies to all uses of this term in this application, including in any claims. As a further example, as used in this application, the term circuitry also covers an implementation of merely a hardware circuit or processor (or multiple processors) or portion of a hardware circuit or processor and its (or their) accompanying software and/or firmware. The term circuitry also covers, for example
20 and if applicable to the particular claim element, a baseband integrated circuit or processor integrated circuit for a mobile device or a similar integrated circuit in server, a cellular network device, or other computing or network device.

[0034] There are two main approaches to improve end-user throughput and to keep delay under control, namely, Channel Selection (CS) and Channel Bonding (CB). CS
25 refers to as an action of selecting a primary 20 MHz transmitting channel. CB refers to a technique to combine a set of adjacent non-overlapping wireless channels in order to create a single channel of wider bandwidth as shown in Fig. 1. CB is introduced with 802.11n (also known as Wi-Fi 4) where two adjacent 20 MHz channels can be merged together to form one 40 MHz channel, while 802.11ac (also known as Wi-Fi 5) provides
30 channels with the bandwidth up to 160 MHz. While the technology of CS has been

studied as independent optimization problem in WLANs, it is important to have an effective dynamic spectrum assignment technique which may select both optimal channel and channel width to maximize Quality of User Experience (QoE). Thus, joint channel and bandwidth optimization refer to as spectrum optimization.

- 5 [0035] To cope with interference and contention problems, proactive spectrum optimization (channel index and channel width) is a crucial feature for every Wi-Fi Access Point (AP). Today Wi-Fi networks consist of legacy 802.11 standards (a/b/g) and the newer ones (11n/11ac/11ax), what more emphasizes the importance of proper spectrum selection. Only as example, as shown in Fig. 2, the available channels are 36,
 10 40, 44 and 48. There is one 802.11n neighboring AP (neighAP) which is operating on channel 36 with the channel width of 40 MHz. There are 5 high active wireless stations associated to neighAP and each of them supports channel bonding of 40 MHz. The problem is what are the optimal channel number and channel width for the 802.11ac AP to achieve the highest performance.
- 15 [0036] Most of available CS methods may select channel 44 or 48 as the optimal channels. Per default channel width in 802.11ac APs is set to 80 MHz. However, in this example, as shown in Fig. 3, the performance of this channel width is worse than for the lowest channel width of 20 MHz. Channel width selection of 80 MHz means that the home AP may compete with 5 STAs and one AP to win a medium. Higher
 20 number of contending participants, lower throughput and higher delay. Although optimal primary channel is selected, wrong channel width selection wipes out the optimality of CS. Channel width of 40 MHz is optimal with optimal channel numbers 44 or 48. There is no delay due to contention with neighboring AP and its STAs and the throughput is maximized. To obtain the values of throughput for optimal channel
 25 48 and 3 possible channel widths 20/40/80 MHz, one 4x4 11ac STA is associated to the home AP and perform throughput testing for downlink, uplink and bi-directional traffic. As shown in Fig. 3, this example shows that the highest achievable throughput can be achieved with lower channel width. Moreover, lower channel width means lower required transmitted power. Thus, the proper spectrum selection has impact on power
 30 usage, as well.

[0037] The Spectrum Optimization problem becomes more critical in dynamic and

unmanaged environment and heterogeneous WMN where selected spectrum should be optimal for each existing 802.11 standard in WMN and for inter-connected mesh points.

[0038] The methods for CS in WMN have been in focus of researchers for more than two decades and they are treated mostly as independent optimization problem.

5 Although, there are many CS methods, they may be broadly classified into three groups based on CS trigger:

[0039] (1) Static – CS is done once in the beginning;

[0040] (2) Periodic – CS is performing periodically;

10 [0041] (3) Threshold based – once monitored metric achieves the threshold value CS is triggered.

[0042] The first two groups cannot deal with dynamic environment, while the last group is sensitive to chosen metric for performance monitoring and the user-defined threshold value. Threshold based CS may stack in local minimum where the performance are not optimal at each time instant. One new approach is proposed where the CS is based on channel interference by using one additional radio to scan continuously all available channels and to obtain the updated information about all channels. By having updated channel information the channel, switching can be performed each time when new optimal channel is observed. However, it is pure chosen metric (interference), then it is AP-based and doesn't take into account users' locations. Therefore it cannot solve hidden node problems.

20 [0043] Dynamic Channel Bonding (DCB) has attracted researchers in the past few years. It discusses effects on throughput and fairness of DCB in spatially distributed high density (HD) wireless local area networks (WLANs). It is shown that the widest available channel maximizes the individual long-term throughput, while the fairness is deteriorated among other WLANs. An integer non-linear model for DCB and it is shown has been proposed where maximal throughput performance can be achieved with DCB under the CS scheme with the least overlapped channels among WLANs. The conventional DCB methods didn't take dynamicity of environment, unmanaged neighboring APs and WMN.

30 [0044] To encompass dynamicity, heterogeneity and unmanaged environment, there is a

need for new pro-active, efficient and intelligent dynamic spectrum optimization. According to embodiments of the present disclosure, the device determines the target combined channel based on performance information of the channels and the devices in the network. The target combined channel is determined based on dynamic
5 performance of the channels. In this way, the best channel combination is selected and sensitivity to thresholds for detecting problems in the network is avoided.

[0045] Fig. 4 illustrates a schematic diagram of a communication system 400 in which embodiments of the present disclosure can be implemented. The communication system 400, which is a part of a communication network, comprises terminal devices
10 410-1, 410-2, . . . , 410-P (collectively referred to as “terminal device(s) 410” where P is an integer number). The communication system 400 comprises other network devices, for example, a master AP 420 and static APs with wireless backhaul which are referred to as extenders 430-1, 430-2, . . . , 430-M (collectively referred to as “extender(s)430” where M is an integer number). It should be noted that the communication system 400
15 may also comprise other elements which are omitted for the purpose of clarity. The master QP 420 and the extenders 430 may communicate with the terminal devices 410. It is to be understood that the numbers of terminal devices and network devices shown in Fig. 4 are given for the purpose of illustration without suggesting any limitations.

[0046] The communication system 400 may include any suitable number of network devices and terminal devices. Only as an example, there are N available channel specifications in the communication network 400. The master AP 420 and the extenders 430 are configured with R radio interfaces and the radio interfaces is assigned to one channel specification.

[0047] Communications in the communication system 400 may be implemented
25 according to any proper communication protocol(s), including, but not limited to, cellular communication protocols of the first generation (1G), the second generation (2G), the third generation (3G), the fourth generation (4G) and the fifth generation (5G) and on the like, wireless local network communication protocols such as Institute for Electrical and Electronics Engineers (IEEE) 802.11 and the like, and/or any other
30 protocols currently known or to be developed in the future. Moreover, the communication may utilize any proper wireless communication technology, including

but not limited to: Code Divided Multiple Address (CDMA), Frequency Divided Multiple Address (FDMA), Time Divided Multiple Address (TDMA), Frequency Divided Duplexer (FDD), Time Divided Duplexer (TDD), Multiple-Input Multiple-Output (MIMO), Orthogonal Frequency Divided Multiple Access (OFDMA)
5 and/or any other technologies currently known or to be developed in the future.

[0048] Fig. 5 illustrates a flow chart of a method 500 in accordance with embodiments of the present disclosure. The method 500 may be implemented at any suitable devices, for example, terminal devices and/or network devices. Only for the purpose of illustrations, the method 500 is described to be implemented at the master AP 420.

10 [0049] At block 510, the master AP 420 obtains first information of transmission performance on a first set of channels. The first information may be obtained periodically. The master AP may use one radio for passive scanning the first set of channels.

[0050] In some embodiments, the first information may comprise indexes of the first set
15 of channels. Alternatively or in addition, the first information may comprise a busy duration of each of the first set of channels in which the first set of channels was sensed busy. The first information may also comprise data volume on each of the first set of channels. In other embodiments, the first information may comprise a noise level (for example, signal-to-noise ratio) on each of the first set of channels.

20 [0051] In some embodiments, as mentioned above, the method may be implemented at terminal devices. If the method is implemented at the terminal device 410-1, the first information may comprise a retransmission rate on each of the first set of channels. Alternatively or in addition, the first information may comprise an error rate on each of the first set of channels. The first information may further comprise signal strength on
25 each of the first set of channels.

[0052] At block 520, the master AP 420 receives second information of transmission performance on the second set of channels from other devices, for example, the extenders 430 and the terminal devices 410. Similarly, the second information may comprise indexes of the second set of channels. Alternatively or in addition, the
30 second information may comprise a busy duration of each of the second set of channels in which the second set of channels was sensed busy. The second information may

also comprise data volume on each of the second set of channels. In other embodiments, the second information may comprise a noise level on each of the second set of channels.

[0053] In some embodiments, if the second information is received from the terminal devices 410, the second information may comprise a retransmission rate on each of the second set of channels. Alternatively or in addition, the second information may comprise an error rate on each of the second set of channels. The second information may further comprise signal strength on each of the second set of channels. In some embodiments, the master AP 420 may periodically notify the extenders 430 and/or the terminal devices 410 to transmit second information to the master AP 420. Alternatively, the extenders 430 and/or the terminal devices 410 may transmit second information to the master AP 420 in a predetermined period.

[0054] FIG. 6 illustrates a flow diagram of a method 600 for obtaining information of transmission performance in accordance with an embodiment of the present disclosure. It is to be understood that the method 600 is merely exemplary and not limiting. The method 600 may be implemented at any suitable devices. Only for the purpose of illustrations, the method 600 is described to be implemented at the master AP 420.

[0055] At block 610, the master AP 420 may obtain transmission environment information for a plurality of network devices. The extenders 430 and/or the terminal devices 410 may directly transmit the transmission environment information to the master AP 420. The extenders 430 and/or the terminal devices 410 may also store transmission environment information into a memory (for example, a cloud storage) accessible by the master AP 420.

[0056] In some embodiments, the transmission environment information may include transmission information of a channel with the network device and transmission information of the terminal device connected to the network device. For example, the network device 430-1 and the indexes of the channels on which it is occupied, the length of time the channel is occupied, the amount of data transmitted on the channel, the noise level on the channel, and the like are transmitted to the master AP 420 as transmission information of the channels. It should be understood that the transmission information of the channels may be any combination of one or more of the

foregoing information, and the transmission information of the channels may also include other information indicating a transmission condition of the channels (for example, a signal to noise ratio). Embodiments of the present disclosure are not limited in this regard.

- 5 [0057] At block 620, the master AP 420 determines the first information of transmission performance based on the transmission environment information. Only as an example, the master AP 420 may determine a ratio of channel occupancy of the network device as below:

$$u_h = \left\lfloor \frac{\text{channel busy time}}{\text{dot11ChannelUtilizationBeaconIntervals} \times \text{dot11BeaconPeriod} \times 1024} \times 255 \right\rfloor \quad (1)$$

where u_h represents a ratio of channel occupancy.

- 10 [0058] Alternatively or in addition, the master AP 420 may determine an average error rate of the devices on a certain channel (for example, the channel d_k^i) as below:

$$\overline{\text{error_rate}}_{d_k^i} = \frac{\sum_{s \in \text{associated STAs}} \text{error_rate}_s}{\text{number of associated STAs to radio } d_k^i} \quad (2)$$

where d_k^i represents an index of the channel; s represents the terminal devices; $\overline{\text{error_rate}}_{d_k^i}$ represents the average error rate on the channel d_k^i ;

- 15 error_rate_s represents the error rate of the terminal device s on the channel d_k^i .

[0059] In some embodiments, the average rate on a channel (for example, the channel d_k^i) may be obtained as below:

$$\overline{\text{retries_rate}}_r = \frac{\sum_{s \in \text{associated STAs}} \text{retries_rate}_s}{\text{number of associated STAs to radio } d_k^i} \quad (3)$$

where d_k^i represents an index of the channel; s represents the terminal devices;

- 20 $\overline{\text{retries_rate}}_r$ represents the average retransmission rate on the channel d_k^i ;
 retries_rate_s represents the error rate of the terminal device s on the channel d_k^i .

[0060] In some embodiments, the master AP 420 may utilize machine learning methods to obtain information of transmission performance. In some embodiments, the

Q-learning (Reinforcement Learning RL) may be used to update Q-values for current applied spectrum channels in WMN.

[0061] Under limited number of channel specifications, the aim is to maximize sum of end-to-end rewards per user as below:

5

$$\max_{C,B} \sum_{k \in U} r_k \quad (4)$$

[0062] The reward per terminal device k is represented as below:

$$r_k = (1 - P_{e,k})(1 - P_{r,k})R_k \quad (5)$$

where $P_{e,k}$ represents error rate for k-th terminal device; $P_{r,k}$ represents
10 retransmission rate for k-th terminal device; and R_k represents goodput of k-th terminal device.

[0063] In some embodiments, the reward takes into account the level of terminal devices' goodput's clearness. If the terminal device is influenced by hidden node problem, then error rate may be high, although the terminal device goodput can be high.
15 Also for exposed node problem, the number of transmitter bytes may be high but most of them are due to retries.

[0064] In some embodiments, the instantaneous reward in the state s for selected channel a at node v_i is given as below:

$$r_t(s, a, v_i) = \sum_{k \in U} r_k \quad (6)$$

20 where s represents the state of the terminal device (for example, the terminal device 410-1); a represents the switching action that the terminal device can perform; v_i represents the i-th network device, and r_k represents the end-to-end user throughput.

[0065] In Q-learning, the cumulative reward $Q(s, a, v_i)$ is calculated using the previous Q-value and the instantaneous reward which is represented as below:

$$Q(s_t, a_t, v_t) := (1 - \eta)Q(s_t, a_t, v_t) + \eta \left[r_{t+1} + \gamma \max_{\forall a_{t+1} \in \mathcal{A}} Q(s_{t+1}, a_{t+1}, v_t) \right] \quad (7)$$

where $Q(s_t, a_t, v_t)$ is the accumulative reward at state s and a channel a taken at time t ; r_{t+1} is the reward obtained by taking action a_t and then making the transition from state s_t to state s_{t+1} ; and parameters η and γ , respectively, are the learning factor and discount rate with values between 0 and 1. The learning factor η controls the convergence speed of the learning. The discount rate γ is used to weight near-term rewards. Specifically, the closer γ is to 1, the greater the weight of future rewards. Q-value is updated with sensing information.

[0066] In some embodiments, the technology of deep neural network (DNN) may be used. The DNN is pre-trained offline for some default scenarios, where is learnt the impact of certain network parameters (such are channel utilization, overlapping impact, hidden node impact) to the reward r_k . During online phase, the DNN learns more specific features for a certain environment (like the terminal devices' behavioral patterns, neighbors' behavioral patterns and the like). The input to the DNN may present the current network state for whole WMN obtained by sensing, a certain combined channel and its Q-value. The DNN may transform this input for that combined channel to a weight which presents predicted reward. The DNN may be called for each combined channel, since only the current applied combined channel in the communication network 400 is used to correct the weights matrices of the hidden layers of DNN. In some embodiments, the LSTM type of DNN may be used.

[0067] At block 630, the master AP 420 may store the first information of transmission performance. The first information may be stored at the master AP 420 locally. Alternatively, the first information may be stored in cloud storage. In some embodiments, the master AP 420 may update the historical information of transmission performance based on the first and/or second information of transmission performance.

[0068] Referring back to Fig. 4, the master AP 420 determine a target combined channel based on the first and second information. In some embodiments, the master AP 420 may determine the target combined channel with the best transmission performance. For example, the master AP 420 may consider the reward of different combined channels and select the one with the highest reward.

[0069] In some embodiments, the master AP 420 may determine the current combined channel (referred to as “the first combined channel”) which is currently used by the master AP 420. The master AP 420 may compare the current combined channel with the target combined channel.

5 [0070] For example, the master AP 420 may take the outputs of DNN and the current reward. If the difference between the target combined channel and the first combined channel exceeds a predetermined threshold value, the master AP 420 may switch to the target combined channel. For example, if there is the target combined channel of which the predicted reward is higher than a certain threshold (for example, 15%) of the
10 current reward, the master AP 420 may switch from the current combined channel to the target combined channel. If the difference between the target combined channel and the first combined channel does not a predetermined threshold value, the master AP 420 may not switch to the target combined channel.

[0071] In this way, at each time instant the best combined channel may be selected and
15 sensitivity to thresholds for detecting problems in the WMN is avoided. Moreover, RL optimal policy is estimated by DNN, and trial and errors are minimized.

[0072] In some embodiments, an apparatus for performing the method 600 (for example, the terminal device 110-1) may comprise respective means for performing the corresponding steps in the method 600. These means may be implemented in any
20 suitable manners. For example, it can be implemented by circuitry or software modules.

[0073] In some embodiments, the apparatus comprises: means for obtaining, at a first device, first information of transmission performance on a first set of channels in a communication network; means for receiving, at the first device and from a second
25 device in the communication network, second information of transmission performance on a second set of channels; and means for determining a target combined channel from the first and second sets of channels based on the first and second information.

[0074] In some embodiments, the first information comprises at least one of: an index of each of the first set of channels, busy duration of each of the first set of channels, data
30 volume on each of the first set of channels, or a noise level on each of the first set of channels.

[0075] In some embodiments, the first device is a terminal device, the first information comprises at least one of: a retransmission rate on each of the first set of channels, an error rate on each of the first set of channels, signal strength on each of the first set of channels, or a noise level on each of the first set of channels.

5 [0076] In some embodiments, the apparatus further comprises: means for updating, with the first and second information, historical information of transmission performance on the first and second sets of channels.

[0077] In some embodiments, the apparatus further comprises: means for determining a first combined channel which is used by the first device; means for comparing the first
10 combined channel with the target combining of channel; and means for in response to a difference of transmission performance between the target combined channel and the first combined channel exceeding a threshold value, switching from the first combined channel to the target combined channel.

[0078] In some embodiments, the first information of transmission performance is
15 obtained at a predetermined period.

[0079] In some embodiments, the second information of transmission performance is received at a predetermined period.

[0080] Fig. 7 is a simplified block diagram of a device 700 that is suitable for implementing embodiments of the present disclosure. The device 700 may be
20 implemented at the network devices, for example, the master AP 420 and the extenders 430. The device 700 may also be implemented at the terminal devices 110. As shown, the device 700 includes one or more processors 710, one or more memories 720 coupled to the processor(s) 710, one or more transmitters and/or receivers (TX/RX) 740 coupled to the processor 710.

25 [0081] The processor 710 may be of any type suitable to the local technical network, and may include one or more of general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs) and processors based on multicore processor architecture, as non-limiting examples. The device 700 may have multiple processors, such as an application specific integrated circuit chip that is slaved in time
30 to a clock which synchronizes the main processor.

[0082] The memory 720 may be of any type suitable to the local technical network and may be implemented using any suitable data storage technology, such as a non-transitory computer readable storage medium, semiconductor based memory devices, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory, as non-limiting examples.

[0083] The memory 720 stores at least a part of a program 730. The device 700 may load the program 730 from the computer readable medium to the RAM for execution. The computer readable medium may include any types of tangible non-volatile storage, such as ROM, EPROM, a flash memory, a hard disk, CD, DVD, and the like. Fig. 8 shows an example of the computer readable medium 800 in form of CD or DVD. The computer readable medium has the program 730 stored thereon.

[0084] The TX/RX 740 is for bidirectional communications. The TX/RX 740 has at least one antenna to facilitate communication, though in practice an Access Node mentioned in this application may have several ones. The communication interface may represent any interface that is necessary for communication with other network elements.

[0085] The program 730 is assumed to include program instructions that, when executed by the associated processor 710, enable the device 700 to operate in accordance with the embodiments of the present disclosure, as discussed herein with reference to Figs. 5 and 6. That is, embodiments of the present disclosure can be implemented by computer software executable by the processor 710 of the device 700, or by hardware, or by a combination of software and hardware.

[0086] While this specification contains many specific implementation details, these should not be construed as limitations on the scope of any disclosure or of what may be claimed, but rather as descriptions of features that may be specific to particular embodiments of particular disclosures. Certain features that are described in this specification in the context of separate embodiments can also be implemented in combination in a single embodiment. Conversely, various features that are described in the context of a single embodiment can also be implemented in multiple embodiments separately or in any suitable sub-combination. Moreover, although features may be described above as acting in certain combinations and even initially

claimed as such, one or more features from a claimed combination can in some cases be excised from the combination, and the claimed combination may be directed to a sub-combination or variation of a sub-combination.

[0087] Similarly, while operations are depicted in the drawings in a particular order, this should not be understood as requiring that such operations be performed in the particular order shown or in sequential order, or that all illustrated operations be performed, to achieve desirable results. In certain circumstances, multitasking and parallel processing may be advantageous. Moreover, the separation of various system components in the embodiments described above should not be understood as requiring such separation in all embodiments, and it should be understood that the described program components and systems can generally be integrated together in a single software product or packaged into multiple software products.

[0088] Various modifications, adaptations to the foregoing exemplary embodiments of this disclosure may become apparent to those skilled in the relevant arts in view of the foregoing description, when read in conjunction with the accompanying drawings. Any and all modifications will still fall within the scope of the non-limiting and exemplary embodiments of this disclosure. Furthermore, other embodiments of the disclosures set forth herein will come to mind to one skilled in the art to which these embodiments of the disclosure pertain having the benefit of the teachings presented in the foregoing descriptions and the associated drawings.

[0089] Therefore, it is to be understood that the embodiments of the disclosure are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are used herein, they are used in a generic and descriptive sense only and not for purpose of limitation.

WHAT IS CLAIMED IS:

1. A device, comprising:
at least one processor; and
5 a memory coupled to the at least one processor, the memory storing instructions therein, the instructions, when executed by the at least one processor, causing the device to:
obtain, at the device, first information of transmission performance on a first set of channels in a communication network;
10 receive, at the device and from a further device in the communication network, second information of transmission performance on a second set of channels;
and
determine a target combined channel from the first and second sets of channels based on the first and second information.
15
2. The device of claim 1, wherein the first information comprises at least one of:
an index of each of the first set of channels,
busy duration of each of the first set of channels,
data volume on each of the first set of channels, or
20 a noise level on each of the first set of channels.
3. The device of claim 1, wherein the device is a terminal device, the first information comprises at least one of:
a retransmission rate on each of the first set of channels,
25 an error rate on each of the first set of channels,
signal strength on each of the first set of channels, or
a noise level on each of the first set of channels.
4. The device of claim 1, wherein the device is further caused to:
30 update, with the first and second information, historical information of transmission performance on the first and second sets of channels.

5. The device of claim 1, wherein the device is further caused to:
determine a first combined channel which is used by the device;
compare the first combined channel with the target combining of channel; and
in response to a difference of transmission performance between the target
5 combined channel and the first combined channel exceeding a threshold value, switch
from the first combined channel to the target combined channel.

6. The device of claim 1, wherein the first information of transmission
performance is obtained at a predetermined period.
10

7. The device of claim 1, wherein the second information of transmission
performance is received at a predetermined period.

8. A method, comprising:
15 obtaining, at a first device, first information of transmission performance on a
first set of channels in a communication network;
receiving, at the first device and from a second device in the communication
network, second information of transmission performance on a second set of channels;
and
20 determining a target combined channel from the first and second sets of channels
based on the first and second information.

9. The method of claim 8, wherein the first information comprises at least one
of:
25 an index of each of the first set of channels,
busy duration of each of the first set of channels,
data volume on each of the first set of channels, or
a noise level on each of the first set of channels.

10. The method of claim 8, wherein the first device is a terminal device, the first
information comprises at least one of:
30 a retransmission rate on each of the first set of channels,

an error rate on each of the first set of channels,
signal strength on each of the first set of channels, or
a noise level on each of the first set of channels.

5 11. The method of claim 8, further comprising:
updating, with the first and second information, historical information of
transmission performance on the first and second sets of channels.

10 12. The method of claim 8, further comprising:
determining a first combined channel which is used by the first device;
comparing the first combined channel with the target combining of channel; and
in response to a difference of transmission performance between the target
combined channel and the first combined channels exceeding a threshold value,
switching from the first combined channel to the target combined channel.

15 13. The method of claim 8, wherein the first information of transmission
performance is obtained at a predetermined period.

20 14. The method of claim 8, wherein the second information of transmission
performance is received at a predetermined period.

25 15. A computer readable medium storing instructions thereon, the instructions,
when executed by at least one processing unit of a machine, causing the machine to
perform the method according to any one of claims 8-14.

30 16. An apparatus, comprising:
means for obtaining, at the apparatus, first information of transmission
performance on a first set of channels in a communication network;
means for receiving, at the apparatus and from a further apparatus in the
communication network, second information of transmission performance on a second
set of channels; and

means for determining a target combined channel from the first and second sets of channels based on the first and second information.

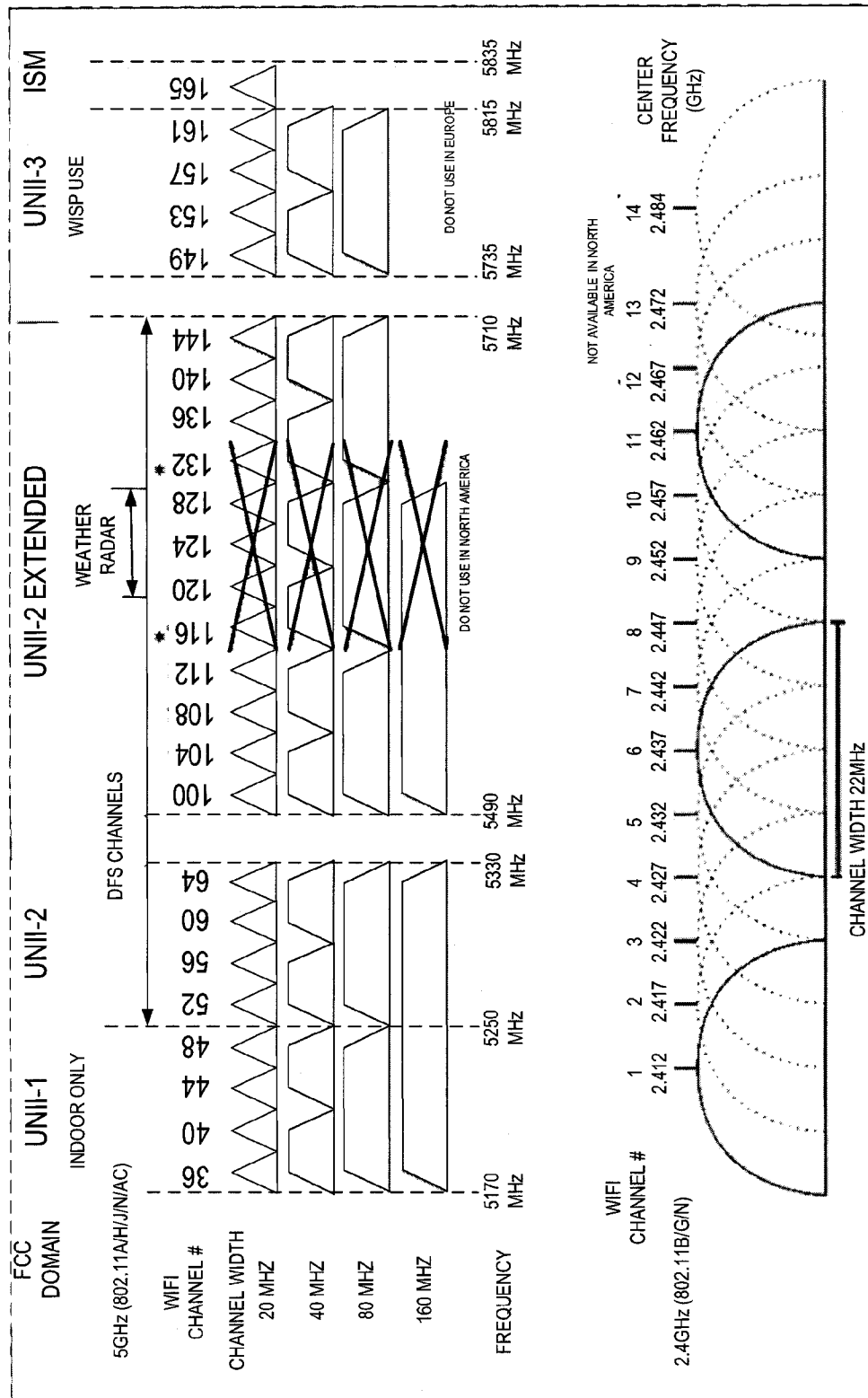


FIG. 1

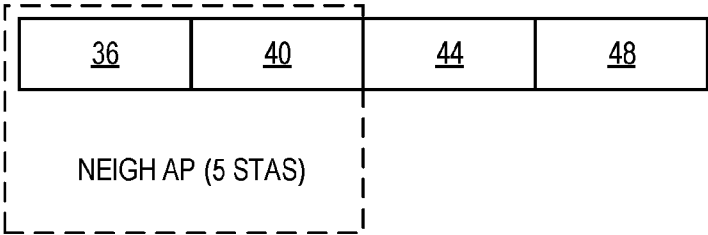


FIG. 2

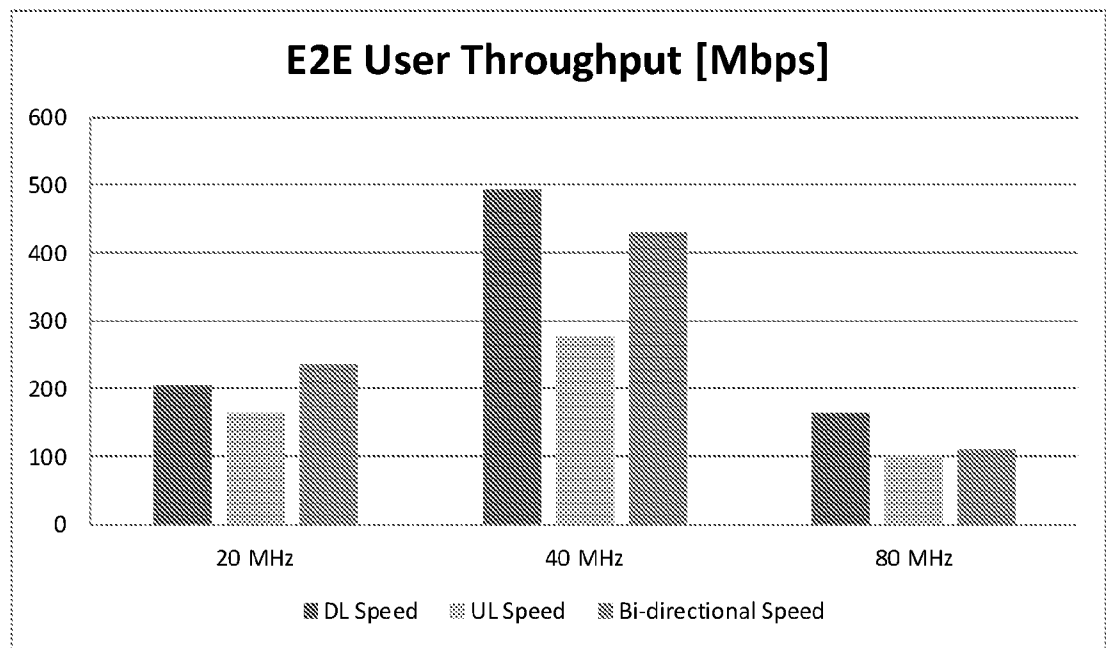


FIG. 3

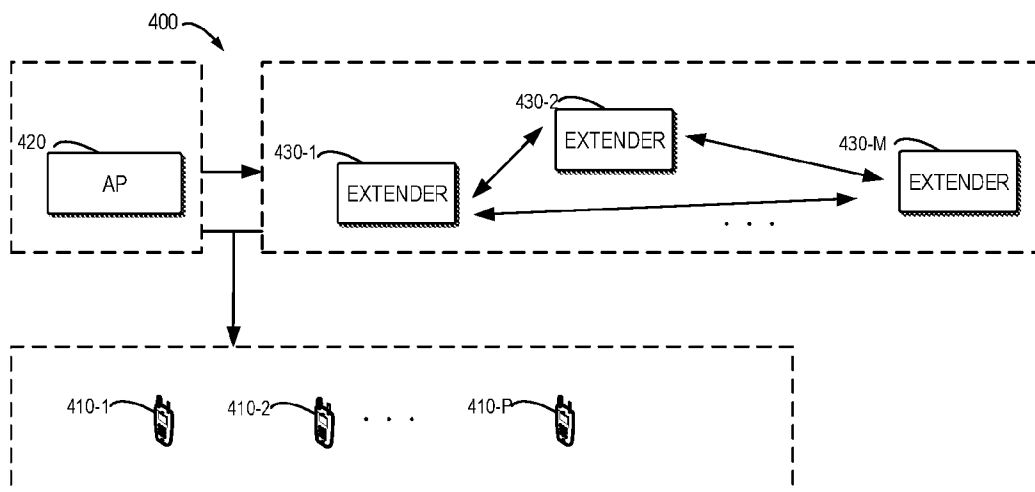


FIG. 4

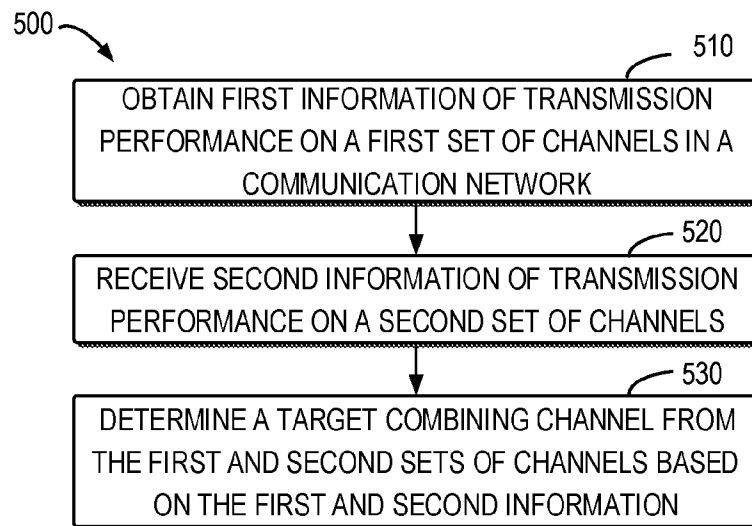


FIG. 5

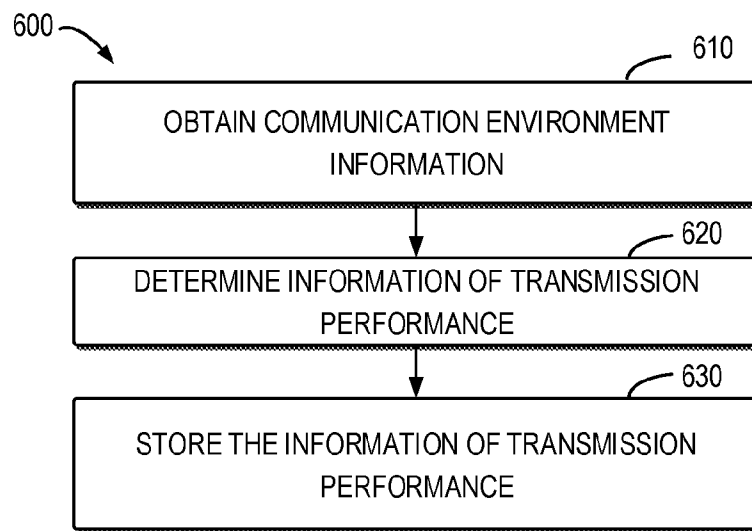


FIG. 6

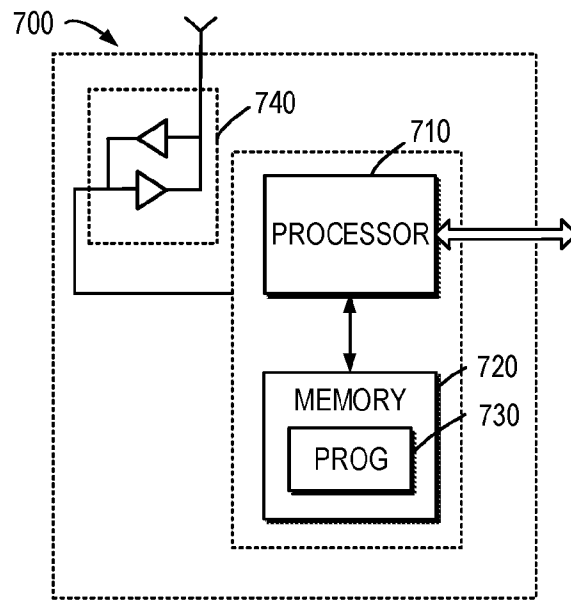


FIG. 7

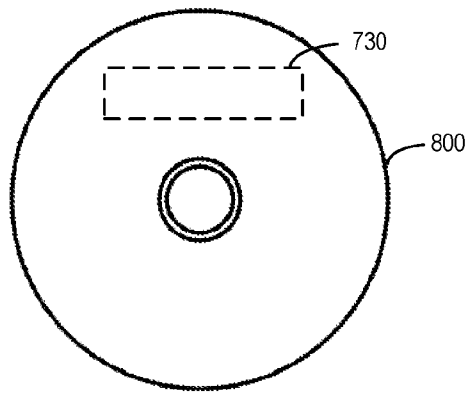


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2019/074751

A. CLASSIFICATION OF SUBJECT MATTER

H04W 72/04(2009.01)i; H04L 5/00(2006.01)i

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)

H04W72/-;H04L5/-

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)

CNABS,CNTXT,CNKI,VEN,USTXT,WOTXT,EPTXT:channel?,combin+,bond+,aggregat+,dynamic,DCB,performance

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 9544222 B2 (CHARETTE KEITH ET AL.) 10 January 2017 (2017-01-10) description, paragraphs [0028]-[0050], [0079]-[0081], figures 1, 2 and 6-8	1-16
X	CN 106664567 A (HUAWEI TECH CO., LTD.) 10 May 2017 (2017-05-10) description, paragraphs [0041]-[0048], [0072]-[0074], figures 1 and 10	1-4, 7-11, 13-16
A	CN 106470488 A (HUAWEI TECH CO., LTD.) 01 March 2017 (2017-03-01) the whole document	1-16

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

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

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

“&” document member of the same patent family

Date of the actual completion of the international search

28 September 2019

Date of mailing of the international search report

25 October 2019

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Telephone No. 86-(010)-62411295

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2019/074751

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
US	9544222	B2	10 January 2017	US	2014192710	A1	10 July 2014
CN	106664567	A	10 May 2017	US	10070319	B2	04 September 2018
				EP	2984861	B1	13 September 2017
				ES	2645948	T3	11 December 2017
				US	2016113026	A1	21 April 2016
				BR	112015018389	A2	18 July 2017
				EP	2984861	A1	17 February 2016
				WO	2016000758	A1	07 January 2016
CN	106470488	A	01 March 2017	None			