



- (51) **International Patent Classification:**
H04W 72/12 (2009.01)
- (21) **International Application Number:**
PCT/US2012/057796
- (22) **International Filing Date:**
28 September 2012 (28.09.2012)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (71) **Applicant:** NOKIA CORPORATION [FI/FI]; Keilalahdentie 4, 02150 Espoo (FI).
- (71) **Applicant (for LC only):** NOKIA INC. [US/US]; Attn: IPR Docketing, 200 South Mathilda Avenue, Sunnyvale, CA 94086 (US).
- (72) **Inventors:** KIM, Taejoon; 2113 Hearst Avenue, Berkeley, CA 94794 (US). DOPPLER, Klaus, Franz; 2054 University Avenue, Berkeley, CA 94704 (US). CHOUDHURY, Sayantan; 2054 University Avenue, Berkeley, CA 94704 (US). JIN, Zhong-Yi; 909 Madison St, Apt. #B, Albany, CA 94706 (US). DOMINGOS, Robson; SCS Quadra 1, Bloco F, 60 Andar 70, 397-900 Brasilia (BR). ALMEIDA, Erik Portel Lope De; Av. Torquato Tapajós 7200, Colônia Terra Nova, 69093-415 Manaus (BR). CHAVES, Fabiano; Av. Torquato Tapajós 7200, Colônia Terra Nova, 69093-415 Manaus (BR). CAVALCANTE, Andre Mendes; Av. Torquato Tapajós 7200, Colônia Terra Nova, 69093-415 Manaus (BR). PAIVA, Rafael, Cauduro, Dias,

De; Av. Torquato Tapajós 7200, Colônia Terra Nova, 69093-415 Manaus (BR). JUNIOR, Fuad, Mousse, Abinader; Av. Torquato Tapajós 7200, Colônia Terra Nova, 69093-415 Manaus (BR). COSTA, Felipe Miranda; Av. Torquato Tapajós 7200, Colônia Terra Nova, 69093-415 Manaus (BR).

- (74) **Agent:** NOKIA CORPORATION; c/o Nokia Inc., Attn: IPR Docketing, 200 South Mathilda Avenue, Sunnyvale, CA 94086 (US).
- (81) **Designated States** (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.
- (84) **Designated States** (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,

[Continued on next page]

- (54) **Title:** NULL SUBFRAME INDICATION FOR COEXISTENCE BETWEEN DIFFERENT NETWORK TYPES

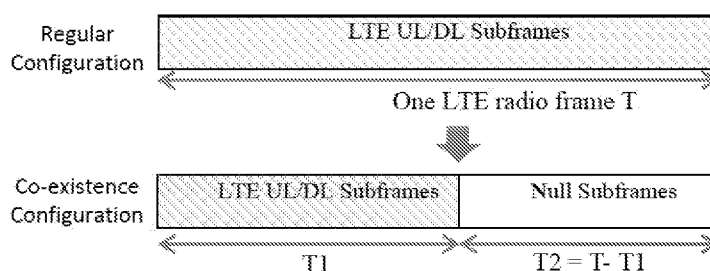


Figure 2

(57) **Abstract:** Communication systems that operate in the same areas of radio frequency spectrum may benefit from coexistence techniques. For example, wireless communication systems may benefit from a null subframe indication for coexistence between different network types. A method may, for example, include detecting, at a first radio access technology, the presence of a second radio access technology. The method can also include indicating information about a null power subframe or of a low power subframe of the first radio access technology to the detected second radio access technology.



TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, **Published:**
ML, MR, NE, SN, TD, TG).

— *with international search report (Art. 21(3))*

Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

**NULL SUBFRAME INDICATION FOR COEXISTENCE
BETWEEN DIFFERENT NETWORK TYPES**

5 **BACKGROUND:**

Field:

 Communication systems that operate in the same areas of radio frequency spectrum may benefit from coexistence techniques. For example, wireless communication systems may benefit from
10 a null subframe indication for coexistence between different network types.

Description of the Related Art:

 In wireless communications, coexistence issues can occur when different systems operate by sharing the same communication resources, such as time, frequency, and space. For instance, with the
15 recent evolution of digital television (TV) broadcasting, substantial amount of spectrum has been available in the very high frequency (VHF) and ultra high frequency (UHF) bands, which is referred to as TV white space (WS). In TVWS, unlicensed devices have access to whitespace database (WSD) to obtain a list of unoccupied spectrum in which the unlicensed devices are allowed to transmit and receive data.

20 Long term evolution (LTE) of the third generation partnership project (3GPP) and WiFi are examples of dominant radio technologies in their respective application areas. Moreover, LTE and WiFi can be deployed in the same unlicensed frequency band and LTE can operate in a time division duplex (TDD) mode.

 However, LTE and WiFi are designed for different applications and are not compatible with
25 each other. As a result, the two systems may cause mutual interference when they operate within the same frequency band. For instance, when LTE and WiFi are collocated and operating in the same time/frequency resources, LTE may dominate the medium.

 Figure 1 illustrates conventional effects of WiFi/LTE co-existence. As shown in Figure 1, WiFi throughput conventionally approaches zero as LTE approaches full load. One reason for this
30 reduction of throughput may be that WiFi spends considerable amount of time to search for holes in the medium and ultimately drops or otherwise fails to deliver the packet. Moreover, there is no conventional LTE frame synchronization mechanism at WiFi.

SUMMARY:

35 According to certain embodiments, a method includes detecting, at a first radio access technology, the presence of a second radio access technology. The method also includes indicating

information about a null power subframe or of a low power subframe of the first radio access technology to the detected second radio access technology.

In certain embodiments, a method includes operating a device of a second radio access technology. The method also includes detecting information of a null power subframe or of a low power subframe of a first radio access technology.

A non-transitory computer readable medium is, in certain embodiments, encoded with instructions that, when executed in hardware, perform a process. The process includes detecting, at a first radio access technology, the presence of a second radio access technology. The process also includes indicating information about a null power subframe or of a low power subframe of the first radio access technology to the detected second radio access technology.

A non-transitory computer readable medium is, according to certain embodiments, encoded with instructions that, when executed in hardware, perform a process. The process includes operating a device of a second radio access technology. The process also includes detecting information of a null power subframe or of a low power subframe of a first radio access technology.

According to certain embodiments, an apparatus includes at least one processor and at least one memory including computer program code. The at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to detect, at a first radio access technology, the presence of a second radio access technology. The at least one memory and the computer program code are also configured to, with the at least one processor, cause the apparatus at least to indicate information about a null power subframe or of a low power subframe of the first radio access technology to the detected second radio access technology.

In certain embodiments, an apparatus includes at least one processor and at least one memory including computer program code. The at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to operate a device of a second radio access technology. The at least one memory and the computer program code are also configured to, with the at least one processor, cause the apparatus at least to detect information of a null power subframe or of a low power subframe of a first radio access technology.

An apparatus, according to certain embodiments, includes detecting means for detecting, at a first radio access technology, the presence of a second radio access technology. The apparatus also includes indicating means for indicating information about a null power subframe or of a low power subframe of the first radio access technology to the detected second radio access technology.

An apparatus, in certain embodiments, includes operating means for operating a device of a second radio access technology. The apparatus also includes detecting means for detecting information of a null power subframe or of a low power subframe of a first radio access technology.

BRIEF DESCRIPTION OF THE DRAWINGS:

For proper understanding of the invention, reference should be made to the accompanying drawings, wherein:

- Figure 1 illustrates conventional effects of WiFi/LTE co-existence.
- 5 Figure 2 illustrates a difference between a regular configuration and a coexistence configuration, according to certain embodiments.
- Figure 3 illustrates a time domain pattern for detection according to certain embodiments.
- Figure 4 illustrates co-existing LTE and WiFi systems according to certain embodiments.
- Figure 5 illustrates an example of LTE TDD frame structure.
- 10 Figure 6 illustrates an LTE frame structure in coexistence mode with 3 coexistence blank subframes, according to certain embodiments.
- Figure 7 illustrates various elements of joint operation of LTE and WiFi networks, according to certain embodiments.
- Figure 8 illustrates a method according to certain embodiments.
- 15 Figure 9 illustrates another method according to certain embodiments.
- Figure 10 illustrates a system according to certain embodiments.

DETAILED DESCRIPTION:

- In certain embodiments that provide for LTE and WiFi coexistence, the LTE system can
- 20 configure a coexistence frame designed suitable for WiFi to access the medium with reduced interference. The coexistence frame may, for example, include at least one null and/or low power subframe.

- Thus, in certain embodiments sequences or patterns are used to indicate the start of null/low power subframes, duration of null/low power subframe, and the coexistence frame type so that WiFi
- 25 can configure when it should transmit packets, in which packet size it should transmit, and what the current LTE frame configuration type is.

- Thus, for example, LTE can provide a sequence or pattern that can be detected by WiFi to indicate the start of null/low power subframes. Different sequences can indicate different lengths of the null/low power subframe period, such as Sequence1 = 5ms, Sequence2 = 2.5ms, and Sequence3 =
- 30 1ms. Alternatively, the number of transmitted sequences can indicate the length of Null/Low power subframe duration, for example 3 sequences = 5ms, 2 sequences = 2.5ms, 1 sequence = 1ms. In addition, each sequence can be used to identify the LTE coexistence frame configuration. For example, a frame configuration implicitly can indicate the duration of the null/low power subframe.

- In the following discussion, an exemplary framework is described based on time division
- 35 duplex (TDD) LTE. LTE base station (BS)/user equipment (UE) and WiFi devices can share the same frequency band. WiFi can operate under distributed coordination function (DCF) protocol, based on a

carrier sense multiple access (CSMA)/ collision avoidance (CA) mechanism. Meanwhile, LTE uplink/downlink (UL/DL) frames can be generated from predefined frame structures, such as those described in 3GPP technical specification (TS) 36.211; Physical Channels and Modulation (Release 8).

5 The LTE and WiFi devices may be active in the coexistence mode. Specifically, the LTE devices can be aware of the existence of WiFi devices and the WiFi devices can be aware of the existence of the LTE devices.

Figure 2 illustrates a difference between a regular configuration and a coexistence configuration, according to certain embodiments. In a regular configuration, a single LTE radio frame
10 T can be made up of LTE UL/DL subframes. In a coexistence mode, LTE BS/UE can change TDD uplink-downlink configuration to a predefined coexistence frame configuration.

The coexistence configuration can include a combination of LTE TDD UL/DL and null subframes or low power subframes, as shown in Figure 2. In Figure 2, T1 and T2 denote frame times allocated to LTE UL/DL and null subframes, respectively. The time T1 can be determined so that it
15 includes primary synchronization signal (PSS), secondary synchronization signal (SSS), and cell-specific common reference signals (RSs) to support regular channel access of LTE UEs. WiFi may or may not have knowledge about PSS, SSS and RSs. The null subframes can be reserved for WiFi channel access. Thus, during null subframes, LTE UE and BS do not transmit and receive any LTE signals.

20 The comparative length of T1 and T2 is shown as being about equal, but this is not a requirement. For example, the duration of T1 can be dynamically adjusted depending on the traffic load in LTE such that $T1 \leq T1_{\max}$. In addition, when the LTE network is overloaded, LTE can restrict the access of UEs to share the medium with WiFi in coexistence mode.

Once the frame configuration has been changed to coexistence configuration, WiFi access
25 point (AP) and/or station (STA) can individually detect the start of the null subframes in time-domain by using one of following methods

One method that can be used is a method of energy detection (ED). In this method, WiFi devices can perform energy detection (ED) during a time duration longer than T and detect the energy difference between LTE subframes and Null subframes. Using this method, the WiFi devices may be
30 unable to distinguish between Null subframe and uplink subframes with LTE UE transmissions that are hidden from the WiFi device. Thus, the WiFi user equipment (UE) may detect an incorrect frame configuration and transmit during LTE UL periods.

The blank subframes do not need to be only at the end. Thus, Figure 2 should not be understood as suggesting that the blank subframes must be only at the end.

35 Another method that can be used is pattern detection in time domain. Figure 3 illustrates a time domain pattern for detection according to certain embodiments. The WiFi devices can search for

a known pattern, as shown in Figure 3, during a time duration longer than T. The pattern can be inserted in time domain at any suitable place, such as the beginning of the null subframe as shown in Figure 3 or at the end of the null subframe. The sequence can be in the time domain or frequency domain, and thus these examples should not be understood as requiring that the time domain must be used. This pattern can be a sequence, such as, for example, a WiFi preamble, a Zadoff-Chu sequence, a pseudorandom noise (PN) sequence, Barker sequence, or the like.

Multiple orthogonal or semi-orthogonal sequences can be used to indicate different frame configurations and/or null subframe durations. For instance, given three sequences, Sequence 1, Sequence 2, and Sequence 3, each can be assigned its own meaning. For example, Sequence 1 can indicate Coexistence configuration1 with Null subframe duration 1ms, Sequence 2 can indicate Coexistence configuration2 with Null subframe duration 3ms, and Sequence 3 can indicate Coexistence configuration3 with Null subframe duration 6ms.

Alternatively, different known frame configurations can be indicated by using different numbers of sequences. For example, a single sequence can indicate Coexistence configuration3 with Null subframe duration 1ms, two sequences can indicate coexistence configuration2 with Null subframe duration 3ms, and three sequences can indicate coexistence configuration1 with Null subframe duration 6ms. In general, the number of sequences can be equal to the number of different LTE frame configurations.

In the above approaches, the WiFi device may be able to reliably detect null subframes without activating the LTE radio. As will be discussed at greater length below, it may be possible for a WiFi device to transmit a frame decodable by LTE to indicate start/stop of WiFi transmission.

Another method can involve the device having LTE radio capability. If WiFi devices have a separate LTE radio capability, the LTE radio can follow the broadcast channel and can know the LTE frame configuration. This knowledge is used at the WiFi radio of the device. This embodiment may require the WiFi device also to activate the LTE radio, which may consume additional energy.

It may be that all devices within the WiFi network corresponding to a single base station subsystem (BSS) are within the transmission range of an LTE BS. This may be the case because a WiFi network is a short range network.

Figure 4 illustrates co-existing LTE and WiFi systems according to certain embodiments. Based on the frame timing obtained by any of the above methods or combinations thereof, the WiFi system can adjust its medium access duration as shown below such that $T_{cs} + T_{bo} + T_{pck} + T_{ov} < T_2$, where T_{cs} denotes carrier sense (CS) duration, T_{bo} denotes backoff duration, T_{pck} represents the packet length, and T_{ov} denotes the overhead, respectively. Overhead can include, for example, short interframe space (SIFS), DCF interframe space (DIFS), point coordination function (PCF) interframe space (PIFS).

In this example, the practical coexistence frame structure of LTE is investigated. In current LTE standard, 3GPP TS 36.211; Physical Channels and Modulation (Release 8), there are a total of seven configurations with configuration numbers from 0 to 6 as illustrated in Table 1, below. Each radio frame for LTE TDD UL/DL lasts 10ms, where one radio frame can include a total of ten subframes with 1ms of subframe duration each. In Table 1, below, 'D', 'S', 'U', 'P', and, 'G' denote fields for downlink, secondary synchronization signal (SSS), uplink, primary synchronization signal (PSS), and downlink to uplink transition gap, respectively.

TDD UL/DL configuration number	One radio frame (10ms, subframe 1ms)									
	0	1	2	3	4	5	6	7	8	9
0 (existing)	D	S	D	P	G	U	U	U	U	U
1 (existing)	D	S	D	P	G	U	U	D	D	D
2 (existing)	D	S	D	P	G	U	U	D	D	D
3 (existing)	D	S	D	P	G	U	U	D	D	D
4 (existing)	D	S	D	P	G	U	U	D	D	D
5 (existing)	D	S	D	P	G	U	U	D	D	D
6 (existing)	D	S	D	P	G	U	U	D	D	D
7 (coexistence frame)	N	S	D	P	G	U	U	D	D	D
8 (coexistence frame)	N	S	D	P	G	U	U	D	D	D
9 (coexistence frame)	N	S	D	P	G	U	U	D	D	D
10 (coexistence frame for backward compatibility)	M	S	D	P	C	N	N	N	N	N

Table 1 Exemplary coexistence frame structure

On top of the existing configurations, configuration 0-6, LTE can configure coexistence frames with new configuration numbers 7-10, as shown in Table 1. In Table 1, 'N' denotes a null subframe, which is dedicated to WiFi channel access and 'C' represents a known code sequence or pattern in time domain that can be understood by WiFi. Here, as above, WiFi is just one example of a radio access technology other than LTE that may be accommodated by the LTE null subframe. Also, in Table 1 'M' denotes a multimedia broadcast multicast service (MBMS) single frequency network (SFN) subframe, as described in 3GPP TS 36.211; Physical Channels and

Modulation (Release 8).

The change of TDD UL/DL configuration can be notified to devices in the LTE system, using two additional bits, to cover configuration numbers 7, 8, 9, and 10, in a master information block (MIB) carried on the physical broadcasting channel (PBCH) or by adding 2 bits in System
5 Information Block (SIB) carried on the physical downlink shared channel (PDSCH).

Alternatively, one additional bit in combination with the bits for the current configurations can be used to identify configurations 7-10 as well as additional configurations, which may be reserved configurations.

A last configuration can be to provide backward compatibility for UEs having no
10 coexistence capability. When these UEs are deployed in the same frequency band as other UEs operating in coexistence mode, UEs without coexistence capability may fail to understand the current frame. In this case, the LTE can indicate a Multimedia Broadcast and Multicast Service Single Frequency Network (MBMS SFN) subframe (denoted by 'M') in the downlink control channel. This can permit the rest of the subframe to be left blank and can create only limited
15 interference to WiFi. UEs without coexistence capability can decode the MBMS SFN information and avoid using the rest of the frame for measurements. They also may avoid trying to decode the downlink subframes. Depending on implementation, any null frames 'N' can be replaced by 'M' to support the backward compatibility.

As mentioned above, in certain embodiments WiFi nodes can communication with LTE
20 base stations (BSs) in order to configure a coexistence operation mode. These embodiments can be used together with or independently from the embodiments described above. More particularly, certain embodiments provide new signaling mechanisms for WiFi nodes to communicate with LTE base stations in order to configure the coexistence operation mode, which is characterized by a new LTE frame structure, as mentioned above. The coordination of the WiFi
25 channel access with the LTE TDD operation mode can avoid interference between LTE and WiFi.

In the presence of an LTE network, the WiFi nodes can sense the spectrum to identify the LTE TDD frame structure. In coexistence mode, specific frequency-time resources in LTE TDD UL frame, known by both systems, can be reserved to WiFi coexistence requests or beacons. These coexistence beacons announce the presence of WiFi and its intent of using the spectrum in
30 a cooperative manner.

When the WiFi coexistence beacon is detected at the LTE BS, the LTE network can adopt a different frame structure, namely a frame structure in which one or more subframes are blanked. These moments of silence in the LTE network may be called coexistence blank subframes (CBS), as well as null power or low power subframes. The CBSs can be used by the WiFi network, which
35 may know and/or learn their periodicity and time duration, for example, by the mechanism mentioned above. After a certain number of consecutive CBSs with no WiFi activity detected or

sensed, the LTE network can switch back to a previous operation mode, one in which no CBS is adopted. In case of new WiFi requisition, the entire procedure can be repeated.

In certain embodiments, both the LTE system and the WiFi system may be able to obtain the list of channels that can be used for secondary transmission. This list can be referred to as a
5 list of available channels. The list of available channels can be obtained through various techniques, such as geo-location database consultation, spectrum sensing, and the like. The available channels, however, may not be vacant due to the presence of other secondary or license-exempt users.

Moreover, in certain embodiments, both systems may be required to provide coexistence
10 mechanisms for other wireless technologies, for instance, federal communications commission (FCC) Part 15 compliance. Additionally, in certain embodiments WiFi nodes have and/or acquire information about the LTE frame structure by sensing and/or learning the spectrum and detecting the LTE primary synchronization signal (PSS). This knowledge of the LTE frame structure may allow WiFi synchronization with LTE frame in the orthogonal frequency division multiplexing
15 (OFDM) symbol level. Figure 5 illustrates an example of LTE TDD frame structure.

Furthermore, in certain embodiments WiFi nodes may be capable of transmitting coexistence beacons in specific frequency-time resource blocks (RBs) of an LTE frame. The specific RBs may be dedicated to such coexistence beacons.

Herein a radio access technology (RAT) that tries to access the available spectrum may be
20 referred to as a candidate network, and the RAT that already occupies the spectrum may be referred to as the prior network. The following situations are possible: (1) vacant channels within the list of available channels may be sufficient for the operation of the candidate RAT or (2) there either may be no vacant channels within the list of available channels or the existing vacant channels may not be sufficient for the operation of the candidate RAT. Moreover, either of the
25 systems may be candidate or the prior network.

When vacant channels within the list of available channels are sufficient for the operation of the candidate RAT, the candidate network may occupy one vacant channel, or multiple vacant channels, if possible, in its common operation mode. LTE, for example, can use the carrier aggregation feature in order to use multiple frequency bands.

30 When there are no vacant channels within the list of available channels, or the existing vacant channels are not sufficient for the operation of the candidate RAT, then the actions may depend on which network is the candidate network and which network is the prior network.

When a WiFi network is candidate network, and an LTE network is prior network, the WiFi nodes may try to share the spectrum occupied by LTE network. The operation of LTE and
35 WiFi networks may be as follows.

The LTE eNodeB can obtain knowledge about the available channels in the location. The LTE can start its operation with one of its common TDD frame configurations, shown in Table 2.

Uplink-downlink configuration	Downlink-to-Uplink Switch-point periodicity	Subframe number									
		0	1	2	3	4	5	6	7	8	9
0	5 ms	D	S	U	U	U	D	S	U	U	U
1	5 ms	D	S	U	U	D	D	S	U	U	D
2	5 ms	D	S	U	D	D	D	S	U	D	D
3	10 ms	D	S	U	U	U	D	D	D	D	D
4	10 ms	D	S	U	U	D	D	D	D	D	D
5	10 ms	D	S	U	D	D	D	D	D	D	D
6	5 ms	D	S	U	U	U	D	S	U	U	D

Table 2: Uplink-downlink frame configurations for LTE TDD.

5 However, a change may be made on the common LTE TDD frame structure for allowing coexistence with WiFi. The mechanism for coexistence may be based on the reservation of specific resource blocks (RB) in the LTE frame for the reception of WiFi coexistence request signals, or coexistence beacons, without interference to LTE users. The physical random access channel (PRACH) is a control channel that can be used by LTE UEs to request transmission
 10 resources. One random access resource in PRACH is a 1 MHz frequency band, having 6 RBs in frequency domain, by 1 ms to 3 ms time, namely 1 to 3 subframes, according to the PRACH preamble format. In LTE TDD, multiple random access resources can be used per uplink subframe.

Figure 5 illustrates 1 random access resource in subframe #2 in accordance with an example embodiment. Since subframe #2 is for uplink in all configurations in Table 2, it can be reserved for transmission of coexistence request.
 15

In another example embodiment, LTE can adopt 5 ms downlink-to-uplink switch-point periodicity, namely configurations 0, 1, 2, or 6 in Table 2. In these example LTE TDD frame configurations, subframes #2 and #7 are for UL transmission, namely they have PRACH.
 20 Therefore, one or more specific access resources of PRACH known by both LTE and WiFi systems can be reserved in both LTE TDD subframes #2 and #7 for coexistence management. In this example embodiment, if a WiFi device detects LTE PSS, and knows that PSS for LTE TDD is located in the third OFDM symbol of the 3rd and 13th slots, then the WiFi device can determine that an uplink subframe (#2 or #7) will start 11 LTE OFDM symbols after the PSS, as
 25 can be seen from Figure 5. Accordingly, WiFi nodes may be able to use the reserved and known PRACH access resources in subframes #2 and #7 to transmit a coexistence beacon to LTE. The use of subframes #2 and #7 is just one example, and other uplink resources can be used in other embodiments.

If no coexistence request is detected, the current operation mode of LTE can be maintained. However, if a coexistence request is detected, the LTE network can change the LTE frame structure for a configuration supporting the coexistence blank subframe (CBS), namely a
 30

subframe designated to WiFi data transmission. Different configurations, for example, those mentioned above, may be proposed by allocating more than one CBS per frame, according to LTE traffic load, the recurrence of WiFi requests, the estimated number of WiFi nodes, and other factors.

5 Figure 6 illustrates an LTE frame structure in coexistence mode with 3 CBSs according to certain embodiments. The new frame structure can be informed to LTE UEs by LTE control signals, such as master information block (MIB), sent at each 40 ms, or system information block (SIB), present at each subframe. If there is communication between neighboring LTE eNodeBs, they can synchronize in coexistence mode, providing interference-free time instants for WiFi
10 transmission.

Furthermore, the LTE network may perform interference measurements during the CBS. After a certain number N of consecutive CBSs with no WiFi transmission detected, the LTE network can switch back to its initial coexistence operation mode described above.

Meanwhile, the WiFi network may operate in parallel to the LTE network. Figure 7
15 illustrates various elements of joint operation of LTE and WiFi networks, according to certain embodiments.

For example, the WiFi access point (AP) may obtain knowledge about the available channels in its own location. Moreover, the WiFi AP may sense the medium to identify vacant channels among the list of available channels.

20 Then, the WiFi AP may identify whether there is a need for sharing any vacant channels. If the WiFi senses the spectrum and detects the LTE PSS signal shown in Figure 5, the WiFi AP can synchronize with the LTE frame at the OFDM symbol level.

The WiFi nodes can transmit the coexistence beacon using the random access resources of the PRACH in the LTE subframes #2 and #7, which can be reserved for this purpose. The
25 coexistence beacon may be detected by the LTE eNodeB, which can, in response, switch the LTE frame configuration to one supporting CBS. If specific frequency-time resources of PRACH are reserved to WiFi communication with an LTE eNodeB, there may be no LTE transmission on those resources. Accordingly, by simple energy detection the LTE eNodeB may be able to detect the presence of a WiFi coexistence beacon, without the need for decoding.

30 Next, as shown in Figure 7, the WiFi nodes can sense the channel and monitor the occurrence of transmission opportunities during a certain period T_{wait} . T_{wait} can be long enough to permit that in case of LTE changing the frame configuration to support CBS, the LTE eNodeB has time to inform the UEs the new configuration (for example, through SIBs). If no transmission opportunity occurs in the period T_{wait} , the WiFi nodes can resend coexistence beacons.

35 However, if transmission opportunities occur, WiFi nodes can start the CSMA/CA protocol with the following restriction: $T_{sensing} + T_{backoff} + T_{packet} + T_{overhead} < T_{CBS}$. In

this case, T_{sensing} , T_{backoff} , T_{packet} , and T_{overhead} can denote the time duration of carrier sensing, backoff, data packet, and overhead, respectively. Overhead can include, for example, SIFS, DIFS, and PIFS. TCBS can denote the time duration of one CBS, as described with reference to Figure 4 above. If it is identified by WiFi nodes that there are two or more
 5 consecutive CBSs available, then the TCBS can be set to the corresponding time duration of the spectrum opportunity, namely the total time duration of the combined consecutive CBSs.

As mentioned above, the candidate and prior networks can be exchanged. Thus, in certain embodiments, LTE may be the candidate network and WiFi may be the prior network.

In this case, the LTE system can start its common operation and WiFi transmission may
 10 be blocked by LTE interference due to the CSMA/CA procedure in WiFi. Then, the situation may become the same as the previous one, in which LTE is the prior network and WiFi is the candidate one.

In various embodiments, a method can use known sequences, by which WiFi can learn about the start of null/low power subframes and coexistence frame configuration. An example
 15 coexistence frame configuration can be a standard confirming frame structure. The sequence may be suitable for WiFi channel access, since WiFi may always first search a series of sequences, such as a preamble, in the medium. This approach may provide for LTE and WiFi coexistence and may provide for acquiring frame synchronization at WiFi to LTE.

In other embodiments, even in the absence of a concrete methodology how to manage
 20 interference across different networks, certain embodiments can provide functionalities to enable coexistence with minimum changes in the original system configurations of LTE and WiFi. Certain embodiments, however, may involve an increase of complexity in WiFi sensing, such as identification of LTE synchronization signals, and increase in complexity of transmission, such as the use of random access resource in PRACH of LTE subframe #2 or/and #7.

Figure 8 illustrates a method according to certain embodiments. The method may be
 25 performed by a LTE device, such as an LTE eNodeB. As shown in Figure 8, a method can include, at 810, detecting, at a first radio system, the presence of a second radio system. For example, the first radio system and the second radio system can be radio systems of two different radio access technologies, such as LTE and WiFi. In Figure 8, LTE and WiFi are used as examples, although the
 30 method can be performed with respect to other radio access technologies and other radio systems. At 815, the method can include changing a frame configuration from a regular configuration to a co-existence configuration, based on detecting the second radio system.

The method can also include, at 820, indicating, among other things, information, such as a
 35 position of a null power subframe or of a low power subframe of the first radio system to the detected second radio system. The information can be at least one of a start of a null/low power subframe, a duration of a null/low power subframe, or a coexistence frame type.

The indicating can include signaling a predetermined pattern indicative of the information. The predetermined pattern can be one of a set of multiple orthogonal or semi-orthogonal sequences. Alternatively, the predetermined pattern can be a predetermined number of sequences, wherein the predetermined number of sequences is selected from a set of predetermined numbers of sequences.

- 5 The predetermined pattern can be configured to indicate at least one of a start of a null/low power subframe, a duration of a null/low power subframe, or a coexistence frame type.

- The method can further include, at 830, dynamically adjusting a duration of the null power subframe or of the low power subframe based on traffic of the first radio system. Moreover, the method can further include, at 840, sensing a plurality of consecutive null power subframes or low
10 power subframes in which the second radio system is not active and, at 850, changing a frame configuration from a co-existence configuration to a regular configuration.

- Figure 9 illustrates a method according to certain embodiments. The method shown in Figure 9 may be performed by, for example, a WiFi device, such as a WiFi access point or station. As shown in Figure 9, the method may include, at 910, operating a device of a second radio system. The method
15 may also include, at 920, detecting information of a null power subframe or of a low power subframe of a first radio system. The information can be at least one of a start of a null/low power subframe, a duration of a null/low power subframe, or a coexistence frame type.

- The first radio system and the second radio system can be radio systems of two different radio access technologies, such as LTE and WiFi. In Figure 9, LTE and WiFi are used as examples,
20 although the method can be performed with respect to other radio access technologies and other radio systems.

- The detecting can include, at 922, detecting an absence of radio frequency energy during a period. Alternatively, at 925, the detecting can include detecting a predetermined pattern indicative of the information. The predetermined pattern can be one of a set of multiple orthogonal or semi-
25 orthogonal sequences. Alternatively, the predetermined pattern can be a predetermined number of sequences, wherein the predetermined number of sequences is selected from a set of predetermined numbers of sequences. The predetermined pattern can be configured to indicate at least one of a start of a null/low power subframe, a duration of a null/low power subframe, or a coexistence frame type.

- In another alternative, the detecting can include, at 927, using a radio of the first radio system
30 in the device of the second radio system. The method can additionally include, at 930, transmitting a frame detectable by first radio system using the second radio system. The transmitting can include sending a coexistence beacon. The method can also include, at 940, adjusting a medium access duration of the second radio system based on the detected information.

- Figure 10 illustrates a system according to certain embodiments of the invention. In one
35 embodiment, a system may include several devices, such as, for example, LTE device 1010 and WiFi device 1020. The system may include more than one WiFi device 1020 and more than one

LTE device 1010, although only one of each is shown for the purposes of illustration. Each of these devices may include at least one processor, respectively indicated as 1014 and 1024. At least one memory may be provided in each device, and indicated as 1015 and 1025, respectively. The memory may include computer program instructions or computer code contained therein.

5 One or more transceiver 1016 and 1026 may be provided, and each device may also include an antenna, respectively illustrated as 1017 and 1027. Although only one antenna each is shown, many antennas and multiple antenna elements may be provided to each of the devices. Other configurations of these devices, for example, may be provided. For example, LTE device 1010 and WiFi device 1020 may be additionally configured for wired communication, in addition to
10 wireless communication, and in such a case antennas 1017 and 1027 may illustrate any form of communication hardware, without being limited to merely an antenna.

Transceivers 1016 and 1026 may each, independently, be a transmitter, a receiver, or both a transmitter and a receiver, or a unit or device that may be configured both for transmission and reception.

15 Processors 1014 and 1024 may be embodied by any computational or data processing device, such as a central processing unit (CPU), application specific integrated circuit (ASIC), or comparable device. The processors may be implemented as a single controller, or a plurality of controllers or processors.

Memories 1015 and 1025 may independently be any suitable storage device, such as a
20 non-transitory computer-readable medium. A hard disk drive (HDD), random access memory (RAM), flash memory, or other suitable memory may be used. The memories may be combined on a single integrated circuit as the processor, or may be separate therefrom. Furthermore, the computer program instructions may be stored in the memory, which may be processed by the processors, can be any suitable form of computer program code, for example, a compiled or
25 interpreted computer program written in any suitable programming language.

The memory and the computer program instructions may be configured, with the processor for the particular device, to cause a hardware apparatus such as LTE device 1010 and WiFi device 1020, to perform any of the processes described above (see, for example, Figures 2-9). Therefore, in certain embodiments, a non-transitory computer-readable medium may be
30 encoded with computer instructions that, when executed in hardware, may perform a process such as one of the processes described herein. Alternatively, certain embodiments of the invention may be performed entirely in hardware.

Furthermore, although Figure 10 illustrates a system including an LTE device 1010 and a WiFi device 1020, embodiments of the invention may be applicable to other configurations, and
35 configurations involving additional elements, as illustrated and discussed herein. For example, multiple user equipment devices, multiple WiFi devices (including WiFi user equipment devices),

and multiple LTE devices (including LTE user equipment devices) may be present. Some devices may be equipped both as WiFi devices and as LTE devices.

One having ordinary skill in the art will readily understand that the invention as discussed above may be practiced with steps in a different order, and/or with hardware elements in

5 configurations which are different than those which are disclosed. For example, certain embodiments apply to license-exempt bands, such as TVWS bands and unlicensed WiFi bands such as in 2.4GHz and 5 GHz range. However, certain embodiments can also be applicable to frequency bands where LTE is the primary licensed system and WiFi operates as secondary system.

10 Therefore, although the invention has been described based upon these preferred embodiments, it would be apparent to those of skill in the art that certain modifications, variations, and alternative constructions would be apparent, while remaining within the spirit and scope of the invention. In order to determine the metes and bounds of the invention, therefore, reference should be made to the appended claims.

15 Glossary

CBS: coexistence blank subframe

CSMA/CA: carrier sensing multiple access – collision avoidance

FDD: frequency division duplexing

FDM: frequency division multiplexing

20 GP: guard period

IDC: in-device coexistence

MIB: master information block

OFDM: orthogonal frequency division multiplexing

OFDMA: orthogonal frequency division multiple access

25 PRACH: physical random access channel

PUCCH: physical uplink control channel

PSS: primary synchronization signal

RB: resource block

SIB: system information block

30 SSS: secondary synchronization signal

TDD: time division duplexing

TDM: time division multiplexing

TVWS: TV white space (WS)

35

WE CLAIM:

1. A method, comprising:
detecting, at a first radio access technology, the presence of a second radio access technology;
5 and
indicating information about a null power subframe or of a low power subframe of the first
radio access technology to the detected second radio access technology.
2. The method of claim 1, further comprising:
10 changing a frame configuration from a regular configuration to a co-existence configuration,
based on detecting the second radio access technology.
3. The method of claim 1 or claim 2, further comprising:
dynamically adjusting a duration of the null power subframe or of the low power subframe
15 based on traffic of the first radio access technology.
4. The method of any of claims 1-3, wherein the indicating comprises signaling a
predetermined pattern indicative of the information.
- 20 5. The method of any of claims 1-4, further comprising:
sensing a plurality of consecutive null power subframes or low power subframes in which
the second radio access technology is not active; and
changing a frame configuration from a co-existence configuration to a regular
configuration.
25
6. A method, comprising:
operating a device of a second radio access technology; and
detecting information of a null power subframe or of a low power subframe of a first radio
access technology.
30
7. The method of claim 6, wherein the detecting comprises detecting an absence of radio
frequency energy during a period.
8. The method of claim 6, wherein the detecting comprises detecting a predetermined pattern
35 indicative of the information.

9. The method of claim 6, wherein the detecting comprises using a radio of the first radio access technology in the device of the second radio access technology.

10. The method of claim 6, further comprising:
5 transmitting a frame detectable by first radio access technology using the second radio access technology.

11. The method of claim 10, wherein the transmitting comprises sending a coexistence beacon.
10

12. The method of any of claims 6-11, further comprising:
adjusting a medium access duration of the second radio access technology based on the detected information.

13. The method of claim 4 or claim 8, wherein the predetermined pattern comprises one of a set of multiple orthogonal or semi-orthogonal sequences.
15

14. The method of claim 4 or claim 8, wherein the predetermined pattern comprises a predetermined number of sequences, wherein the predetermined number of sequences is selected from a set of predetermined numbers of sequences.
20

15. The method of any of claims 4, 8, 13, or 14, wherein the predetermined pattern is configured to indicate at least one of a start of a null/low power subframe, a duration of a null/low power subframe, or a coexistence frame type.
25

16. The method any of claims 1-15, wherein the information comprises at least one of a start of a null/low power subframe, a duration of a null/low power subframe, or a coexistence frame type.

17. The method of any of claims 1-16, wherein the first radio access technology comprises a long term evolution radio system.
30

18. The method of any of claims 1-17, wherein the first radio access technology comprises a WiFi radio system.

19. A non-transitory computer readable medium encoded with instructions that, when executed in hardware, performs a process, the process comprising the method of any of claims 1-18.
35

20. An apparatus, comprising:
at least one processor; and
at least one memory including computer program code,
wherein the at least one memory and the computer program code are configured to, with the
5 at least one processor, cause the apparatus at least to
detect, at a first radio access technology, the presence of a second radio access technology;
and
indicate information about a null power subframe or of a low power subframe of the first
radio access technology to the detected second radio access technology.

10

21. The apparatus of claim 20, wherein the at least one memory and the computer program
code are configured to, with the at least one processor, cause the apparatus at least to change a frame
configuration from a regular configuration to a co-existence configuration, based on detecting the
second radio access technology.

15

22. The apparatus of claim 20 or claim 21, wherein the at least one memory and the computer
program code are configured to, with the at least one processor, cause the apparatus at least to
dynamically adjust a duration of the null power subframe or of the low power subframe based on
traffic of the first radio access technology.

20

23. The apparatus of any of claims 20-22, wherein the at least one memory and the computer
program code are configured to, with the at least one processor, cause the apparatus at least to indicate
the information by signaling a predetermined pattern indicative of the information.

25

24. The apparatus of any of claims 20-23, wherein the at least one memory and the
computer program code are configured to, with the at least one processor, cause the apparatus at least
to

sense a plurality of consecutive null power subframes or low power subframes in which
the second radio access technology is not active; and

30

change a frame configuration from a co-existence configuration to a regular
configuration.

35

25. An apparatus, comprising:
at least one processor; and
at least one memory including computer program code,
wherein the at least one memory and the computer program code are configured to, with the

at least one processor, cause the apparatus at least to
operate a device of a second radio access technology; and
detect information of a null power subframe or of a low power subframe of a first radio
access technology.

5

26. The apparatus of claim 25, wherein the at least one memory and the computer program
code are configured to, with the at least one processor, cause the apparatus at least to detect the
information by detecting an absence of radio frequency energy during a period.

10

27. The apparatus of claim 25, wherein the at least one memory and the computer program
code are configured to, with the at least one processor, cause the apparatus at least to detect the
information by detecting a predetermined pattern indicative of the information.

15

28. The apparatus of claim 25, wherein the at least one memory and the computer program
code are configured to, with the at least one processor, cause the apparatus at least to detect the
information using a radio of the first radio access technology in the device of the second radio access
technology.

20

29. The apparatus of claim 25, wherein the at least one memory and the computer program
code are configured to, with the at least one processor, cause the apparatus at least to transmit a frame
detectable by first radio access technology using the second radio access technology.

25

30. The apparatus of claim 29, wherein the at least one memory and the computer program
code are configured to, with the at least one processor, cause the apparatus at least to transmit the
decodable frame by sending a coexistence beacon.

30

31. The apparatus of any of claims 25-30, wherein the at least one memory and the computer
program code are configured to, with the at least one processor, cause the apparatus at least to adjust a
medium access duration of the second radio access technology based on the detected information.

35

32. The apparatus of claim 23 or claim 27, wherein the predetermined pattern comprises one
of a set of multiple orthogonal or semi-orthogonal sequences.

35

33. The apparatus of claim 23 or claim 27, wherein the predetermined pattern comprises a
predetermined number of sequences, wherein the predetermined number of sequences is selected from
a set of predetermined numbers of sequences.

34. The apparatus of any of claims 23, 27, 32, or 33, wherein the predetermined pattern is configured to indicate at least one of a start of a null/low power subframe, a duration of a null/low power subframe, or a coexistence frame type.

5 35. The apparatus any of claims 20-34, wherein the information comprises at least one of a start of a null/low power subframe, a duration of a null/low power subframe, or a coexistence frame type.

36. The apparatus of any of claims 20-35, wherein the first radio access technology comprises
10 a long term evolution radio system.

37. The apparatus of any of claims 20-36, wherein the first radio access technology comprises a WiFi radio system.

15 38. An apparatus, comprising:
means for detecting, at a first radio access technology, the presence of a second radio access technology; and
means for indicating information about a null power subframe or of a low power subframe of the first radio access technology to the detected second radio access technology.

20 39. The apparatus of claim 38, further comprising:
means for changing a frame configuration from a regular configuration to a co-existence configuration, based on detecting the second radio access technology.

25 40. The apparatus of claim 38 or claim 39, further comprising:
means for dynamically adjusting a duration of the null power subframe or of the low power subframe based on traffic of the first radio access technology.

41. The apparatus of any of claims 38-40, wherein the indicating comprises signaling a
30 predetermined pattern indicative of the information.

42. The apparatus of any of claims 38-41, further comprising:
means for sensing a plurality of consecutive null power subframes or low power subframes in which the second radio access technology is not active; and
35 means for changing a frame configuration from a co-existence configuration to a regular configuration.

43. An apparatus, comprising:
means for operating a device of a second radio access technology; and
means for detecting information of a null power subframe or of a low power subframe of a
first radio access technology.

5

44. The apparatus of claim 43, wherein the detecting comprises detecting an absence of radio
frequency energy during a period.

45. The apparatus of claim 43, wherein the detecting comprises detecting a predetermined
10 pattern indicative of the information.

46. The apparatus of claim 43, wherein the detecting comprises using a radio of the first radio
access technology in the device of the second radio access technology.

15 47. The apparatus of claim 43, further comprising:
means for transmitting a frame detectable by first radio access technology using the second
radio access technology.

48. The apparatus of claim 47, wherein the transmitting comprises sending a coexistence
20 beacon.

49. The apparatus of any of claims 43-48, further comprising:
means for adjusting a medium access duration of the second radio access technology based
on the detected information.

25

50. The apparatus of claim 41 or claim 45, wherein the predetermined pattern comprises one
of a set of multiple orthogonal or semi-orthogonal sequences.

51. The apparatus of claim 41 or claim 45, wherein the predetermined pattern comprises a
30 predetermined number of sequences, wherein the predetermined number of sequences is selected from
a set of predetermined numbers of sequences.

52. The apparatus of any of claims 41, 45, 50, or 51, wherein the predetermined pattern is
configured to indicate at least one of a start of a null/low power subframe, a duration of a null/low
35 power subframe, or a coexistence frame type.

53. The apparatus any of claims 38-52, wherein the information comprises at least one of a start of a null/low power subframe, a duration of a null/low power subframe, or a coexistence frame type.

5 54. The apparatus of any of claims 38-53, wherein the first radio access technology comprises a long term evolution radio system.

55. The apparatus of any of claims 38-54, wherein the first radio access technology comprises a WiFi radio system.

10

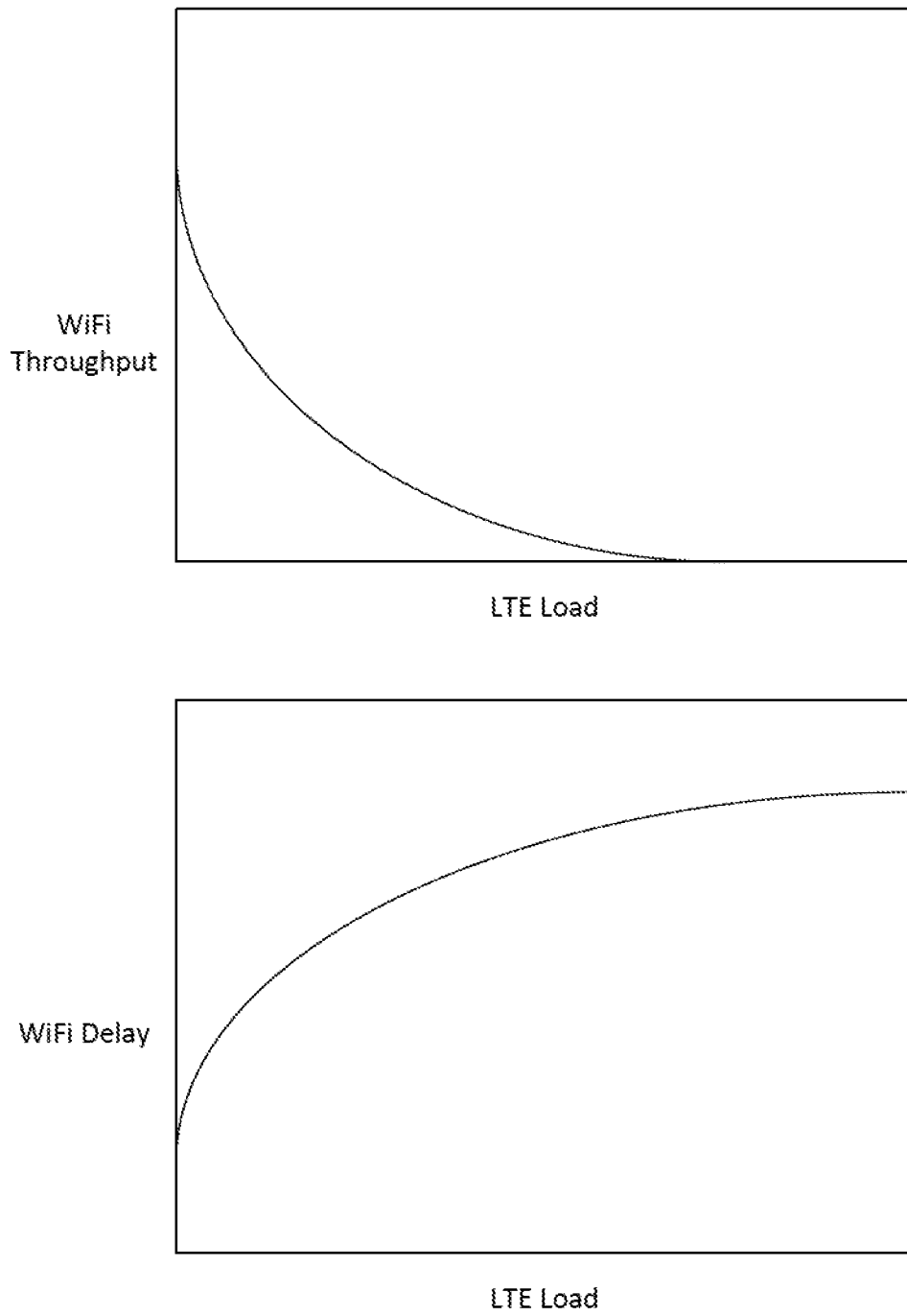


Figure 1

Related Art

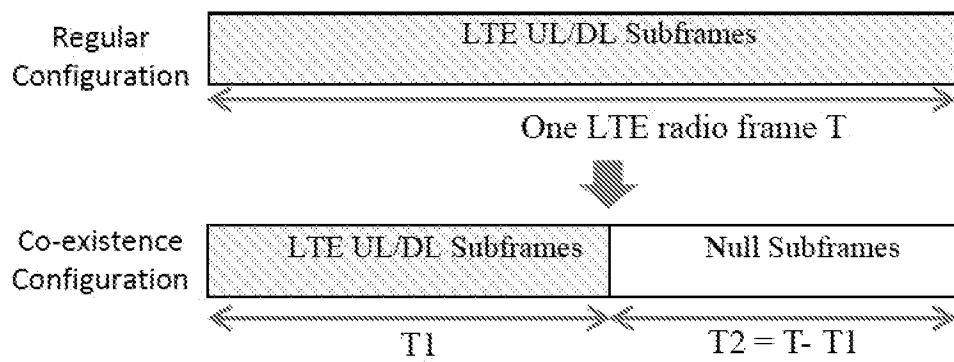


Figure 2

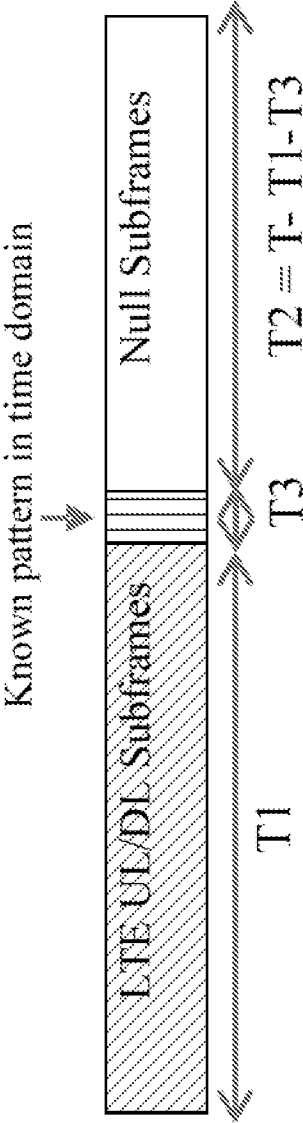


Figure 3

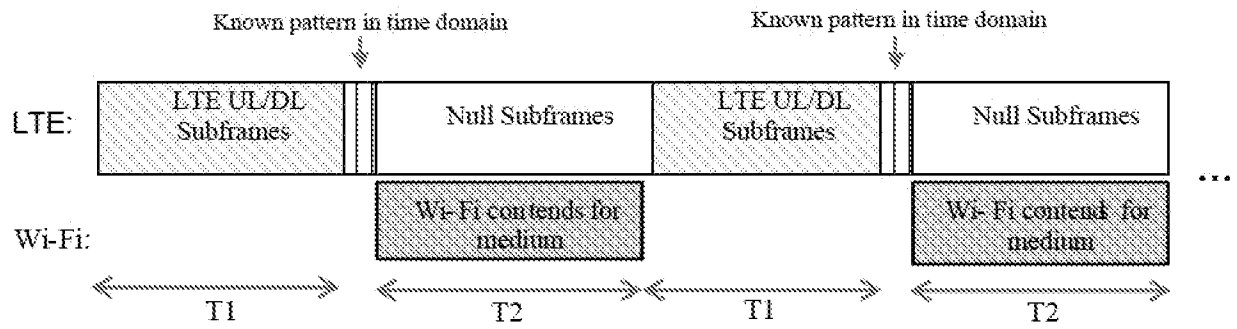


Figure 4

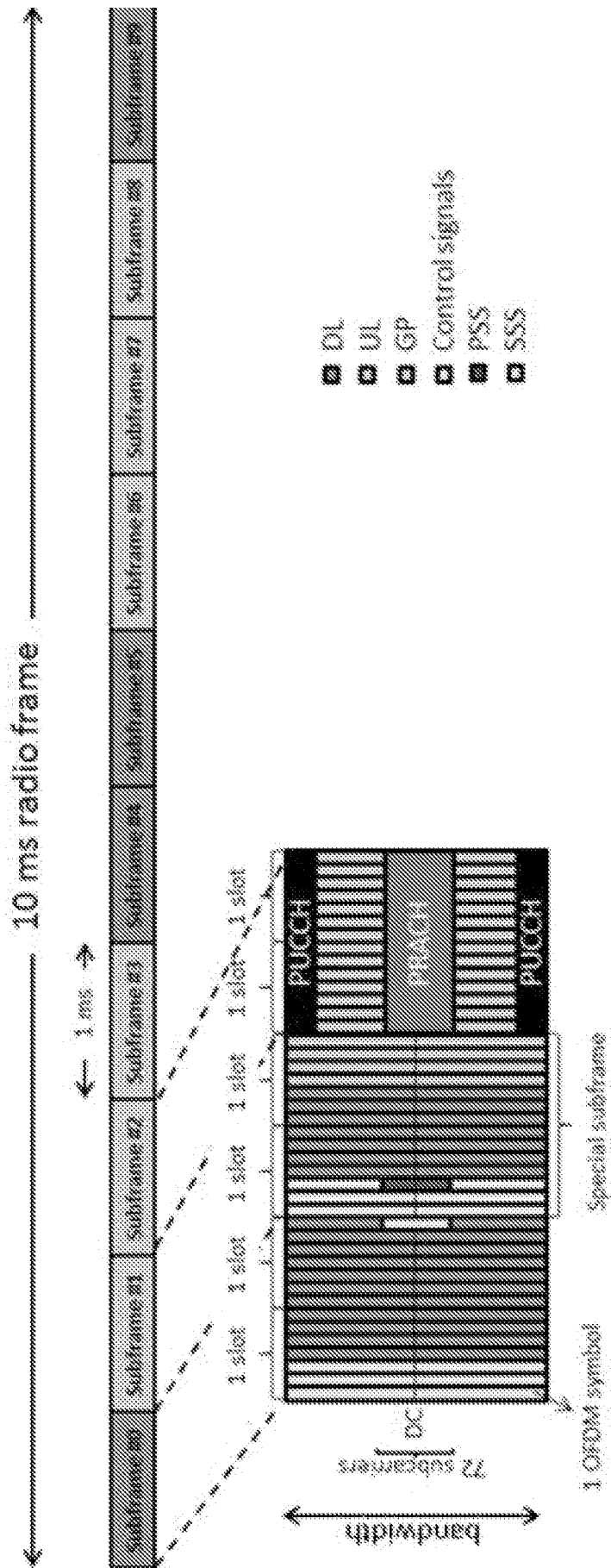


Figure 5

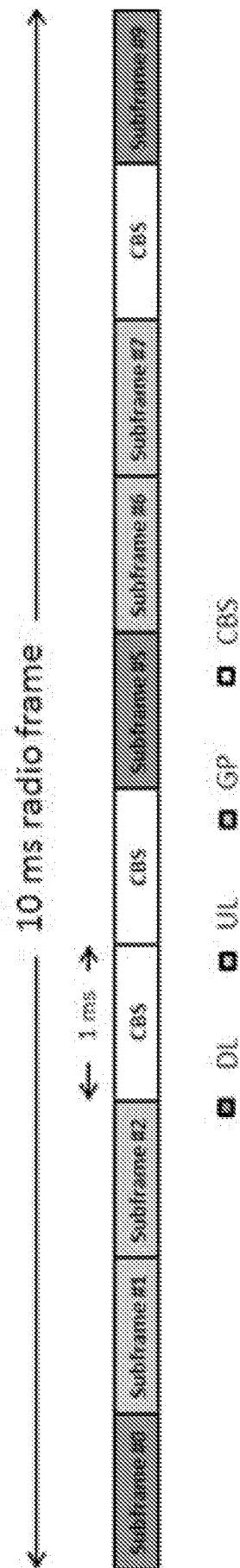


Figure 6

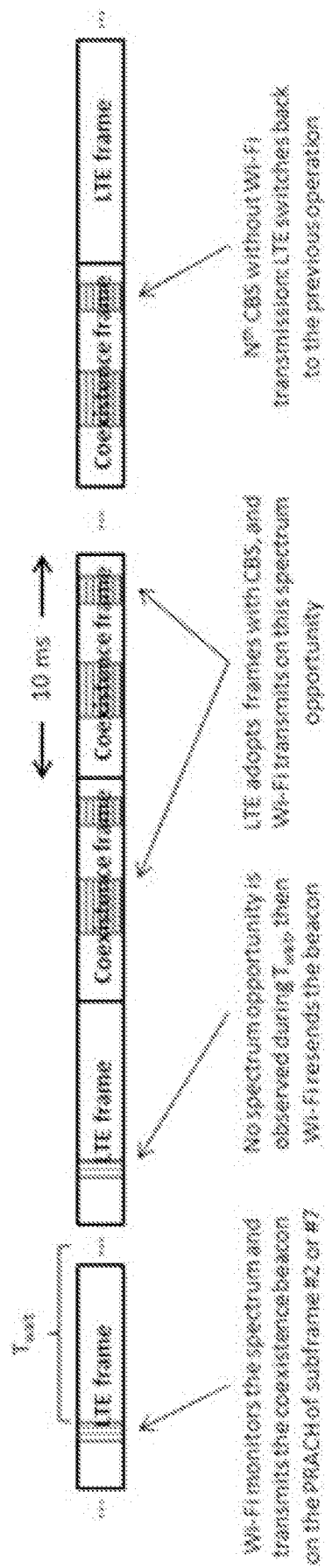


Figure 7

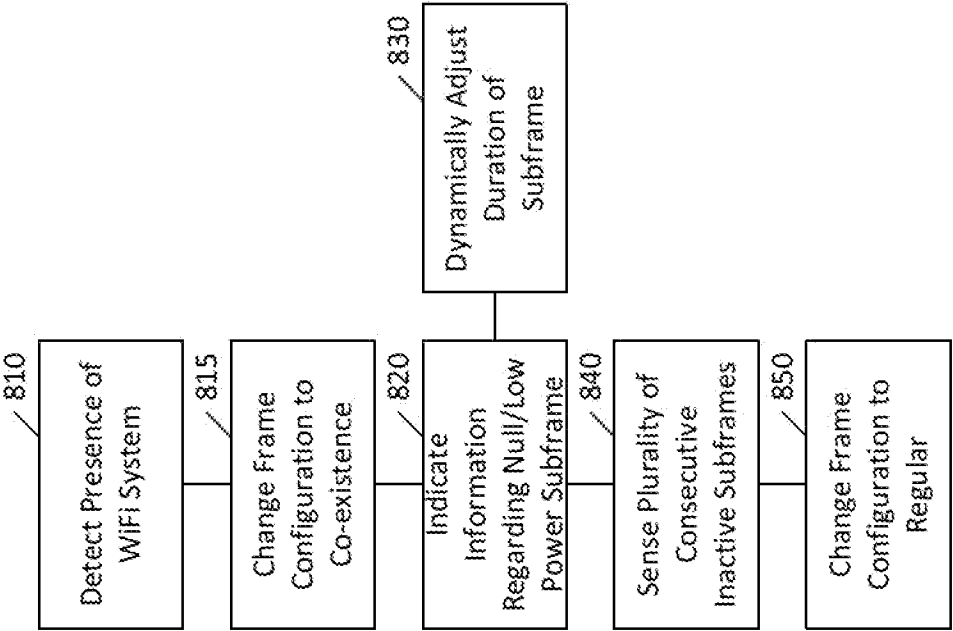


Figure 8

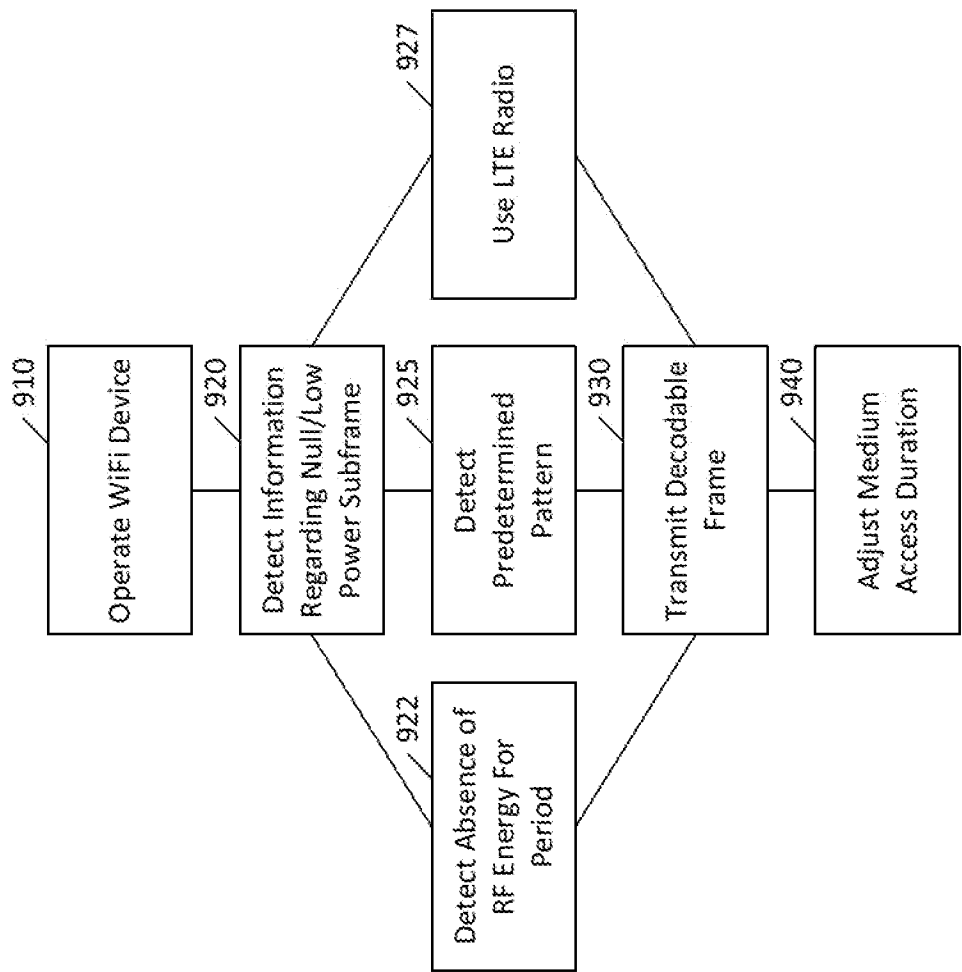


Figure 9

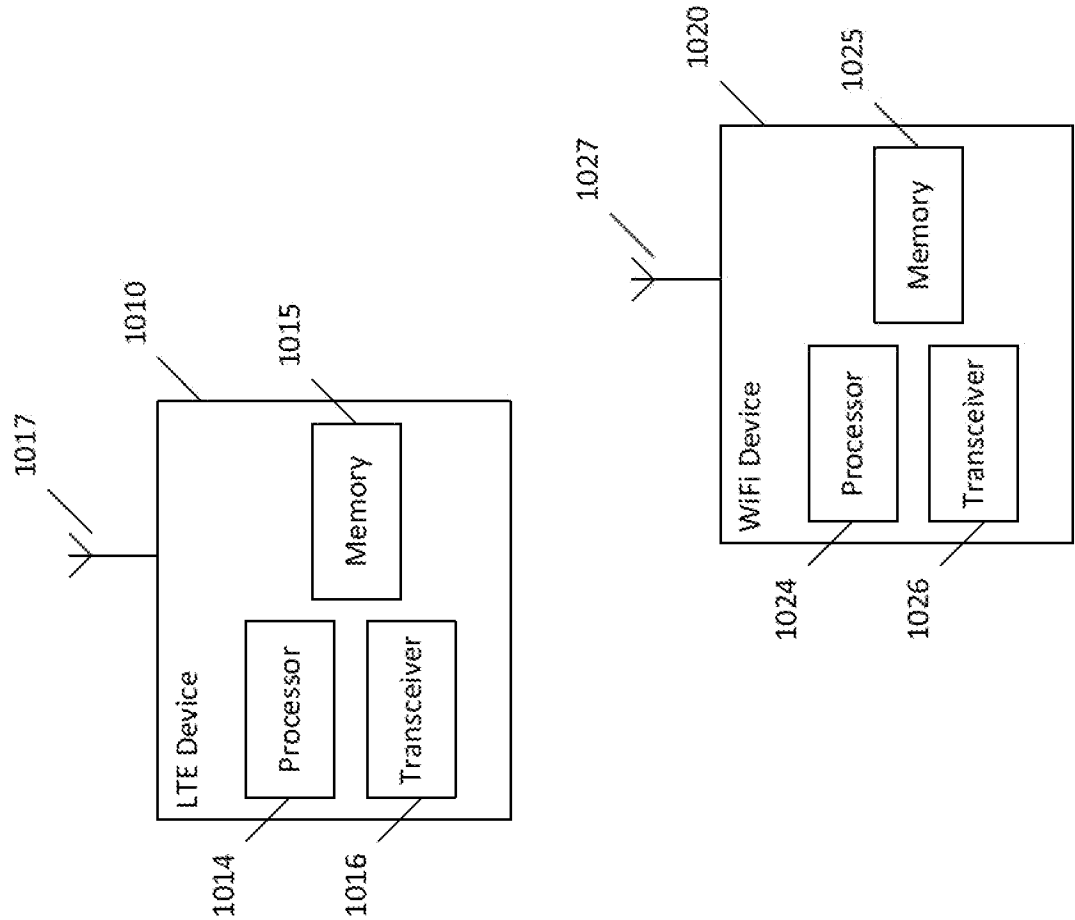


Figure 10

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2012/057796

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - H04W 72/12 (2012.01)

USPC - 370/350

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)

IPC(8) - H04B 1/44; H04W 72/04, 12 (2012.01)

USPC - 370/350; 455/78, 88

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)

MicroPatent, Google Patents, Google Scholar

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X — Y	US 2011/0205986 A1 (MEDAPALLI) 25 August 2011 (25.08.2011) entire document	1-2, 6-9, 20-21, 25-28, 38-39, 43-46 ----- 3, 10-12, 22, 29-31, 40, 47-49
Y	US 2009/0081962 A1 (SOHRABI) 26 March 2009 (26.03.2009) entire document	3, 22, 40
Y	US 2010/0046498 A1 (HALL) 25 February 2010 (25.02.2010) entire document	10-12, 29-31, 47-49
A	US 2011/0312288 A1 (FU et al) 22 Decemebr 2011 (22.12.2011) entire document	1-3, 6-12, 20-22, 25-31, 38-40, 43-49

☐ Further documents are listed in the continuation of Box C.

* Special categories of cited documents:

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

03 December 2012

Date of mailing of the international search report

11 DEC 2012

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-3201

Authorized officer:

Blaine R. Copenheaver

PCT Helpdesk: 571-272-4300
PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2012/057796

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☒ Claims Nos.: 4-5,13-19,23-24,32-37,41-42,50-55
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.