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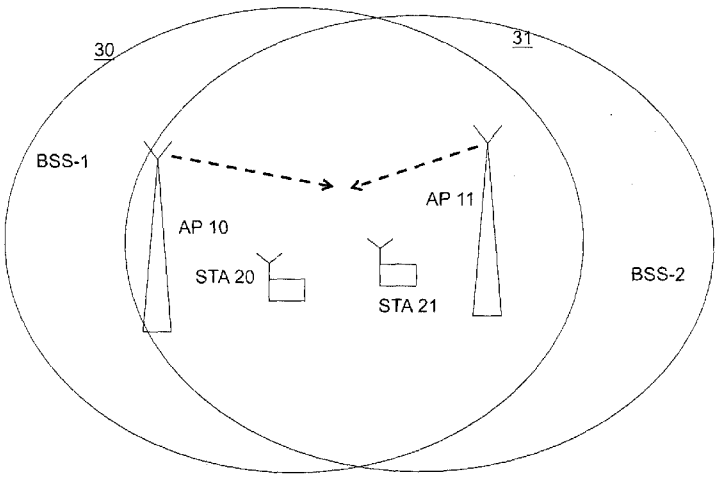
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(54) Title: SECTORIZED BEAM OPERATION FOR WIRELESS NETWORKS



(57) Abstract: A communication method for a wireless network is disclosed. The wireless network comprises a plurality of wireless devices. The method comprises transmitting one or multiple packets with an omni-beam by a first wireless device to a second wireless device in a packet exchange during an omni-beam duration to indicate a sectorized-beam duration, receiving the packet(s) by a third wireless device, transmitting/receiving data by the first wireless device using a sectorized beam in a packet exchange with the second wireless device during the sectorized beam duration, and detecting by the third wireless device the sectorized beam packet(s) from the first wireless device and packet(s) from the second wireless device, if no sectorized beam packet(s)from the first wireless device and packet(s) from the second wireless device is detected, the third wireless device starting to communicating with a fourth wireless device.

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TITLE

SECTORIZED BEAM OPERATION FOR WIRELESS NETWORKS

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a sectorized beam operation in a wireless network, and in particular relates to a sectorized beam operation for reduced interference, enhanced robustness, and increased capacity in multiple, overlapping wireless networks deployment scenarios.

Description of the Related Art

Fig. 1 shows a CSMA-based wireless system with a basic service set 1 BSS-1, including an access point (AP) 10 and a station (STA) 20, and an overlapping basic service set 2 BSS-2, including an access point AP 11 and a station STA 21. The coverage 30 of the basic service set BBS-1 overlaps a part of the coverage 31 of the basic service set BBS-2. The two BSSs are called, overlapping BSS, OBSS. When any of the access points APs 10, 11 or station STAs 20, 21 tries to access the channels for wireless transmission, it performs a channel sensing and a random back-off contention procedure. Any of the station or access point wins the contention can transmit into the wireless medium to gain the transmit opportunities (TXOP) and other stations or access point sense that the channel is busy would defer their transmission until the TXOP is over. Such carrier sense multiple access, (CSMA,)wireless protocol minimizes the likelihood of collision in which more than one station or access point transmit into the wireless medium causing the reception at the intended recipient to fail. In general, the CSMA protocol is intended for devices (station or access point) with omni-direction

antennas such that the all the devices sharing the wireless medium can hear one another. However, if one device cannot hear another device in the same wireless medium, it is called a hidden node. With a hidden node in the wireless network, potential collision can occur since the device is unable to sense the transmission of the other devices. Note that since the two wireless networks (e.g. BSS-1 and BSS-2 in this example) are sharing the same wireless medium for transmission, the achievable throughput of each individual network is reduced whereas the aggregate network throughput of the two wireless networks remains approximately the same. For long range outdoor networks, the increased coverage range results in many overlapping wireless networks within the same area leading to significant reduction in the throughput of the individual network. Therefore, there's a need to manage the communication in wireless networks with overlapping coverage.

SUMMARY OF THE INVENTION

The present invention discloses a wireless communication method. The method comprises transmitting by a first wireless device a sectorized beam duration in an omni-beam duration, and transmitting/receiving data between the first wireless device and a second wireless device using a sectorized beam during the sectorized beam duration.

The present invention also discloses a communication method for a wireless network, wherein the wireless network comprises a plurality of wireless devices. The method comprises transmitting a one or multiple packet(s) with an omni-beam by a first wireless device to a second wireless device in a packet exchange during an omni-beam duration to indicate a sectorized-beam duration, receiving the packets from the first device by a third wireless device, transmitting/receiving

data by the first wireless device using a sectorized beam while exchanging packets with the second device during the sectorized beam duration, and detecting by the third wireless device the sectorized beam packets from the first wireless device and packets from the second wireless device, if no sectorized beam packets from the first wireless device and packets from the second wireless device is detected, the third wireless device starting to communicating with a fourth wireless device.

These and other objectives of the present invention will no doubt become obvious to those of ordinary skill in the art after reading the following detailed description of the preferred embodiment that is illustrated in the various figures and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention can be more fully understood by reading the subsequent detailed description and examples with references made to the accompanying drawings, wherein:

Fig. 1 shows a scenario of two overlapping wireless networks.

Fig. 2 shows a sectorized beam with an omni-beam overlay according to an embodiment of the present invention.

Fig. 3 shows two overlapping wireless networks based on proposed invention. of the present invention. of the present invention. of the present invention. of the present invention.

Fig. 4 illustrates the sector training frame exchange of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 2 provides an illustration of the sectorized beams with an omni-beam overlay. Note that a sectorized beam pattern 110 in Fig. 2(a) can be realized by a panel sector antenna or other synthesized antenna methods. The six sectorized beams 111, 112, 113, 114, 115, 116 in Fig. 2(b) can be realized by duplicating the sectorized beam pattern 110 in Fig. 2(a) six times in 60 degree increments. An omni-beam pattern can also be realized by transmitting through all six sectorized beams simultaneously. It should be noted that these beams can be employed both for transmission and reception. The spatial reciprocity condition in which the transmission and reception uses the same antenna pattern can be a precondition. For those skilled in the art may appreciate that there are many other ways to generate the sectorized beams.

Fig. 3 provides an illustration of the spatially orthogonal frame exchange. The present invention can be based on the sectorizd-beam transmission and reception frame exchange between an access point and a station within a TXOP. In a different TXOP, the frame exchange involving a different sectorized beam can be employed. There may be no dependence from one TXOP to another TXOP. The present invention also does not limit how the BSSs are deployed within a geographical area. For the sake of description, it is assumed that an access point (AP), employs sectorized-beam antennas and the AP can switch between the omni-beam transmission/ reception and the sectorized beam transmission/ reception. However, for those skilled in the art may appreciate that a non-AP station can employ the sectorized-beam transmission and reception and use the present invention.

The sectorization scheme according to an embodiment of the present

invention can be described as two parts. The first part involves the two wireless devices (e.g., an access point 40 and a station 50 in Fig. 3(a)) engages in frame exchange in a TXOP 100 shown in Fig. 3(b). The frame exchange starts with a brief omni-beam frame exchange duration 101 and then follows with the sectorized beam frame exchange duration 102. During the omni-beam transmission duration 101, the access point 40 advertises to all other stations 41, 52, 53, 54 within the range that a frame exchange has started (TXOP 100 obtained), the duration of the frame exchange (via the network allocation vector, NAV, setting), and optionally the intention to switch to a sectorized beam shortly. At the end of the omni-beam transmission duration 101, the access point switches to the sectorized beam transmission/reception 102 for the remainder of the frame exchange. Note that an embodiment of the present invention mandates that the access point continues to use the same sectorized beam transmission/reception through the duration indicated in the NAV setting. Other stations such as STA 51 associated the same BSS receive the frame exchange during the omni-beam transmission duration, defer based on a NAV setting realizing that the access point is busy engaging in a frame exchange with a station for the duration 100.

The second part of the scheme involves how the OBSS access points or stations 41, 52, 53 intending to start a new frame exchange, without waiting for the end of TXOP 100, should detect the spatially orthogonal condition as a pre-condition to spatially reuse the wireless medium. For an OBSS station 52, or 53 or access point 41, the spatially orthogonal condition means that the OBSS station 52, or 53 or access point 41 does not hear the sectorized beam transmission from the access point 40 and the transmission of the station 50 involving in the frame exchange. Having to satisfy this spatially orthogonal condition would prevent the

OBSS station 52, or 53 or access point 41 to interfere with the frame exchange between the Access point 40 and station 50. If the spatially orthogonal condition is met, the OBSS station 52, or 53, or access point 41 is allowed to reset its NAV setting and starts a spatially orthogonal (SO) frame exchange during the sectorized beam duration 102. An embodiment of the present invention mandates that the new SO frame exchange to start with a request to send, (RTS,) and clear to send, (CTS,) exchange. The station which is the intended recipient of the RTS can respond with a CTS only if its NAV setting is zero at the time the RTS is received. This ensures that the intended recipient station of the RTS also does not cause interference to both the station 50 and access point 40 if they are within its range.

Note that the BSS practices the above scheme of the present invention shall indicate the sectorized beam capability during the capability exchange, or in the probe response, association response or other type of packets. Another preferred embodiment is to carry an indicator in a signal preamble or signaling field to alert receiving stations of the frame exchange as described in the above. An OBSS access point or station capable of spatial orthogonal detection does not need to declare the capability but do need to follow the present invention for resetting NAV and for starting a new SO frame exchange. In order to facilitate OBSS access point or station to detect the SO frame exchange, an preferred embodiment is to include an indicator to be carried in a short frame such as clear to send, (CTS) which is transmitted before the sectorized beam frame exchange. This serves as an early indicator to OBSS access point and station that a sectorized beam frame exchange is forthcoming. Note that in the clear to send null data packet, the CTS can be configured as CTS-to-self packet by setting the Address Indicator field to

RA (Receive Address) and the RA/Partial BSSID field to the address of the initiator of the sectorized beam frame exchange. The inclusion of the RA allows OBSS station and access point to know the initiator of the sectorized beam frame exchange.

In summary, the proposed sectorization operation can be defined by the following rules:

- The switching between the omni-directional beam and the sectorization beam occurs during the interframe spacing between two consecutive packets or in-between the omni preamble and the beamformed preamble of a long preamble.
- When an AP is aware of the sector in which a station is in, AP may transmit to or receive from the station using the sectorized beam either during the scheduled transmission such as restricted access window (RAW) or within a TXOP. Otherwise, AP transmits or receives through an omni directional beam to a station.
- Once an AP transmits to a station through a sectorized beam, it shall use the same sectorized beam to receive from the station within the same TXOP.
- Once the AP switches to the sectorized beam transmission during an exchange, it shall continue with the sectorized beam transmission with the same sectorized beam and the TXOP truncation is not allowed for the remainder of the protected duration. If there is transmission failure within the sectorized beamformed duration, the baseline recovery procedure using a PIFS (PCH interframe space) to regain channel access can be used and the same sectorized beam transmission and reception shall be applied.

Note that the forming of the sectorized beam(s) is known to those skilled in the art and is not restricted by the proposed invention. One of the preferred embodiment is to use n antennas to form beams, where n>1.

Note that through sectorized beam transmission and reception, the present invention reduces interference to OBSSs and is less susceptible to the OBSS interference thereby enhancing the robustness of the link. The present invention does not require coordination or synchronization between BSSs for such operation nor does it impose any restrictions on how BSSs should be deployed within a geographical area. This feature is particularly suitable for unlicensed wireless network operation in which BSS are deployed randomly in a geographic area as opposed to deployment of cellular networks which requires careful deployment planning to achieve high capacity. Through spatial re-use of the wireless medium, higher aggregate network capacity can be achieved. Note that the proposed scheme is backward compatible with the existing CSMA-CA based wireless system such as IEEE 802.11.

In the present invention, an AP needs to know the best sector to a station prior to sectorized beam frame exchange. For those skilled in the art may appreciate that there are many ways the sector information can be obtained by an access point and the present invention does not restrict in any way how this knowledge can be obtained. The sector training is one preferred embodiment to help the stations to determine the best sectors to communicate with the AP. Sector training requires the AP to transmit training NDPs (Null Data Packet), each transmitted through a different sectorized beam, over all sectors to allow the receiving stations to determine which sector is the best. The best sector might be chosen by a station based on instantaneous or averaged channel state information

(CSI) or signal-to-noise ratio. The different methods of choosing the sector are known to those skilled in the art.

An embodiment of the NDP for sector training of the present invention is to employ CTS-NDP with the Address Indicator field sets to RA (receive address) and the RA Address/Partial BSSID field is set to partial AID of the AP. This is effectively a CTS-to-self transmission by the access point. The duration setting of the CTS, which counts down to zero in the last CTS-NDP, can be used to derive which sector it is transmitting. These training NDPs shall be transmitted consecutively and should be sent within a single TXOP. The training information is exchanged using a high throughput (HT) variant Control field, which is a format in 802.11ac. The present invention does not prevent AP to use other methods to determine the station's best sector.

Another embodiment of sector training is shown in Fig. 4. Anan AP sends a sector training announcement 200 followed by a series of NDP sector training frames 203, 204 separated by SIFS. The sector training may occur periodically with the training period and the beacon interval in which the frequency of training and schedule beacon time as indicated in information element, e.g., Sector Operation element, carried in the beacon. The sector training may occur in response to a request from a STA, or initiated by the AP. In the case that the AP receives the sector training request from a station, the AP shall initiate a sector training. The total number of sectors is signaled during the AP capability exchange.

Note that the station participation in the sector training is optional. If the station can communicate with the AP well, the station can skip the sector training. The stations may also determine whether it is necessary to feedback the best

sector to the access point or not. Obviously, if the best sector does not change, there is no need to feedback to the access point.

A preferred embodiment for a station to request Sector Training from AP by using the HT Variant Control field 200 if it is capable of sector training request as currently in the IEEE 802.11n and IEEE802.11ac standard amendments. By setting the MAI=14 in the Link Adaptation Control subfield of the HT Variant Control field, the station indicates HT variant control field is used for signaling Sector Training (or Antenna Selection) information. The Sector training (or sector training resumption) is requested by a station when the ASELC subfield is set to 1 and the ASEL Data subfield with values in the range of 1 to 15, being the number of the first NDP training frames to be transmitted when the command is Sector Training Resumption, where 0 corresponds to the first training frame in the Sector Training Request. When the NDP Announcement field is also set to 1, it indicates training NDP frames to follow with two consecutive training NDP frames 203, 204 separated by SIFS.

An embodiment of the present invention of the frame exchange sequence for sector training, where the AP transmits training NDP frames, and the STA provides Sector ID feedback. The frame exchange comprises the following steps:

a. (Optional) A station may initiate the sector training by sending a HTC+ (high throughput control) frame with the ASELC set to 1 for sector training request 202.

b. The AP sends out consecutive training NDPs separated by SIFS in a TXOP of which it is the TXOP holder with no ACK over different sectorized beams. NDP CTS frames, with NDP MAC Frame Type=3, are used in sector training. Each training NDP 203,

204 is transmitted over one sector beam. The first training NDP frame 203 shall be preceded by a HTC+ frame 200 with NDP announcement subfield set to 1. The positions of the training NDP frames correspond to the sector IDs of the sectorized beams, in ascending order starting with Sector ID =0.

c. The station(s) may perform training by estimating the received signal quality corresponding to each training NDP 203, 204.

d. The station(s) engages in the training by receiving the sector training frames may respond with a selected sector ID using the sector ID feedback frame in a subsequent TXOP or during Sector Report RAW which may be indicated by beacon for fast sector discovery of multiple STAs.

If the AP receives a HTC+ MPDU 200 with the MAI subfield equal to 14, the ASEL Command subfield equal to Sector Training Request (=1), and the ASEL Data subfield equal to a zero to correspond to the command Sector Training, the station shall assume a total number of training NDPs that corresponds to the total number of sectors. If the AP receives a HTC MPDU with the MAI subfield equal to 14, the ASEL Command subfield equal to Sector Training Request (=1), and the ASEL Data subfield equal nonzero value to correspond to the command Sector Training Resumption (a Resumption MPDU), the station shall assume the number of training frames that follow the Resumption MPDU is equal to the number of training NDPs from the total number of sectors minus the order number transmitted in the ASEL Data subfield of the Resumption MPDU.

AP may schedule sector sounding for multiple STAs by RAW in a beacon

interval using the RAW Parameter Set element with the Sounding RAW Indication set to 1. During the Sounding RAW, non-AP STAs are prohibited to transmit but can elect to listen to the sector training for the entire RAW. This Sounding RAW may be scheduled in a periodic or impromptu way.

The sector training within the Sounding RAW starts with a frame with NDP announcement indicator set to 1 in the HT control field and is followed in SIFS by a number of NDP CTS frames, each transmitted through different antenna sector starting with Sector ID equal to 0, and separated by SIFS. The Sounding RAW indication sub-field set to 0 indicates no sector sounding is performed within the RAW.

A preferred embodiment of Sector ID feedback is for a station to optionally use a VHT action frame for (solicited and unsolicited) Sector ID feedback.

What is claimed is:

1. A wireless communication method, comprising:

transmitting a protection duration by a first wireless device to a second station in an omni-beam duration of a transmit opportunity;

transmitting/receiving data by the first wireless device using a sectorized beam in a packet exchange with the second device during a sectorized beam duration of the transmit opportunity;

wherein the protection duration covers the sectorized beam duration.

2. The method of claim 1, further comprising,

detecting by a third wireless device a spatial orthogonal condition,

wherein the third wireless device has an overlapping signal range with the first wireless device or the second wireless device..

3. The method of claim 2, further comprising,

setting by the third wireless device a network allocation vector to zero if the spatial orthogonal condition is detected.

4. The method of claim 3, further comprising,

transmitting by the third wireless device a request to send packet to start a new transmit opportunity with a fourth wireless device.

5. The method of claim 1, wherein the sectorized beam is performed by a beamforming via a plurality of antennas.

6. The method of claim 2, wherein the step of transmitting by the first wireless device the sectorized beam duration in an omni-beam duration further comprises,

sending an indicator to the third wireless device informing the sectorized beam is forthcoming.

7. The method of claim 6, wherein the indicator is sent in a clear to send frame.

8. A wireless communication training method, comprising,

transmitting by the first wireless device a sequence of training frames, each through a different antenna sectorized beam, and

comparing by the second wireless device received signal qualities of the training frames to determine the sectorized beam duration according to a predetermined rule.

9. The method of claim 8, further comprising,

transmitting by the first wireless device a sector training announcement.

10. The method of claim 9, wherein the sector training announcement is a frame with a high throughput control (HTC) field.

11. The method of claim 9, further comprising

transmitting by the first wireless device an information element of an occurrence and a frequency of a periodic sector.

12. The method of claim 8, further comprising

transmitting a request sector training by the second wireless device.

13. The method of claim 9, further comprising,

transmitting by the second wireless device a feedback of a best sector.

14. A communication method for a wireless network, wherein the wireless network comprises a plurality of wireless devices, the method comprising,

transmitting a one or multiple packet with an omni-beam by a first wireless device to a second wireless device in a packet exchange during an omni-beam duration to indicate a sectorized-beam duration;

receiving the packet from the first wireless device by a third wireless device;

transmitting/receiving data by the first wireless device using a sectorized beam in the packet exchange with the second device during the sectorized beam duration; and

detecting by the third wireless device the sectorized beam packet from the first wireless device and packet from the second wireless device, if

no sectorized beam packet from the first wireless device and packet from the second wireless device is detected, the third wireless device starting to communicating with a fourth wireless device.

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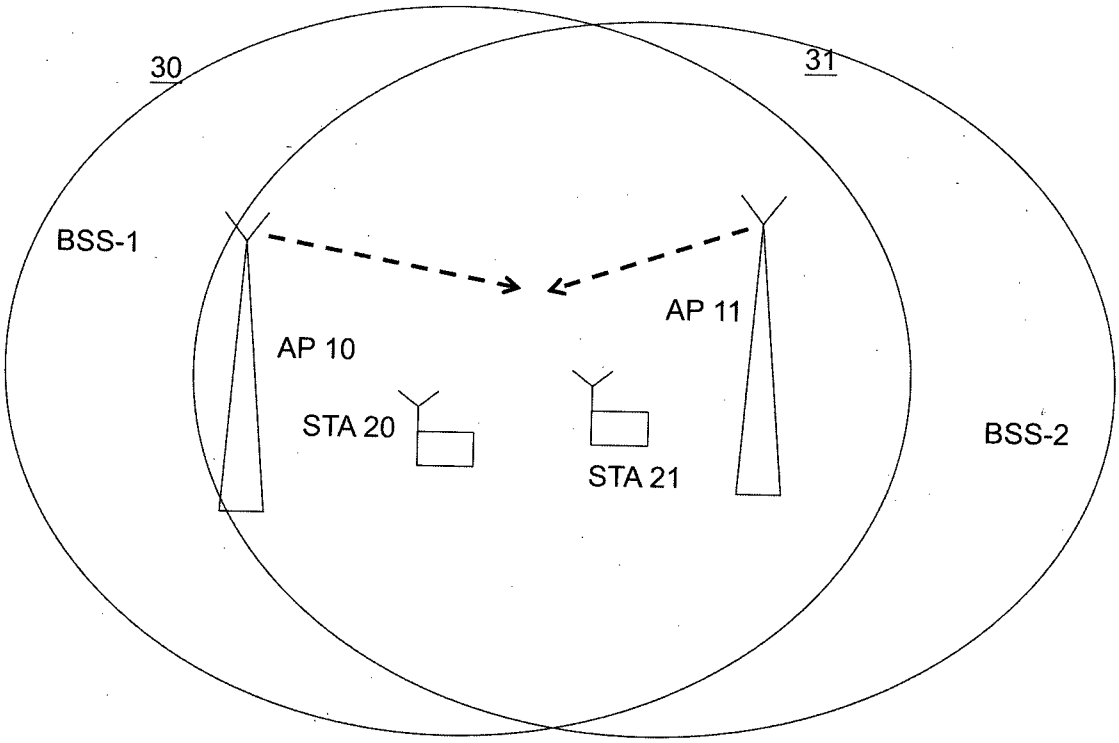
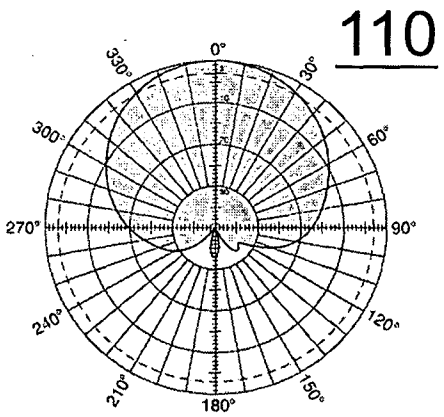
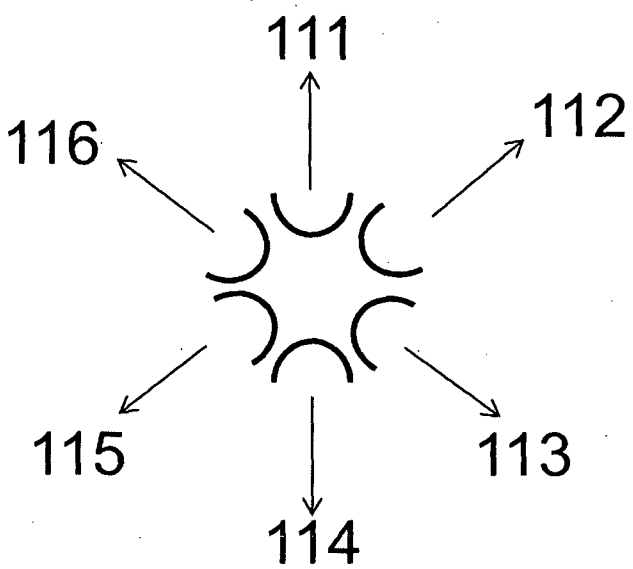


Fig. 1

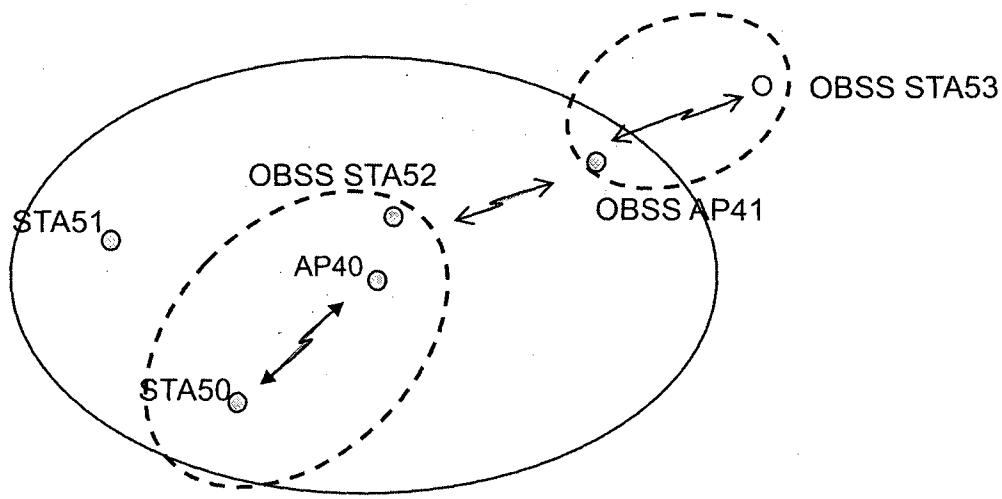

110
0°
30°
60°
90°
120°
150°
180°
210°
240°
270°
300°
330°

(a)

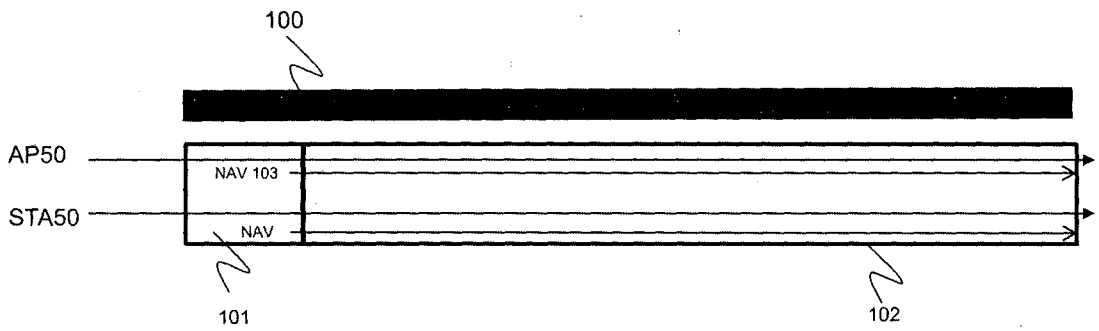

111
112
113
114
115
116

(b)

Fig. 2


OBSS STA53
OBSS STA52
OBSS AP41
STA51
AP40
STA50

(a)


100
AP50
NAV 103
STA50
NAV
101
102

(b)

Fig. 3

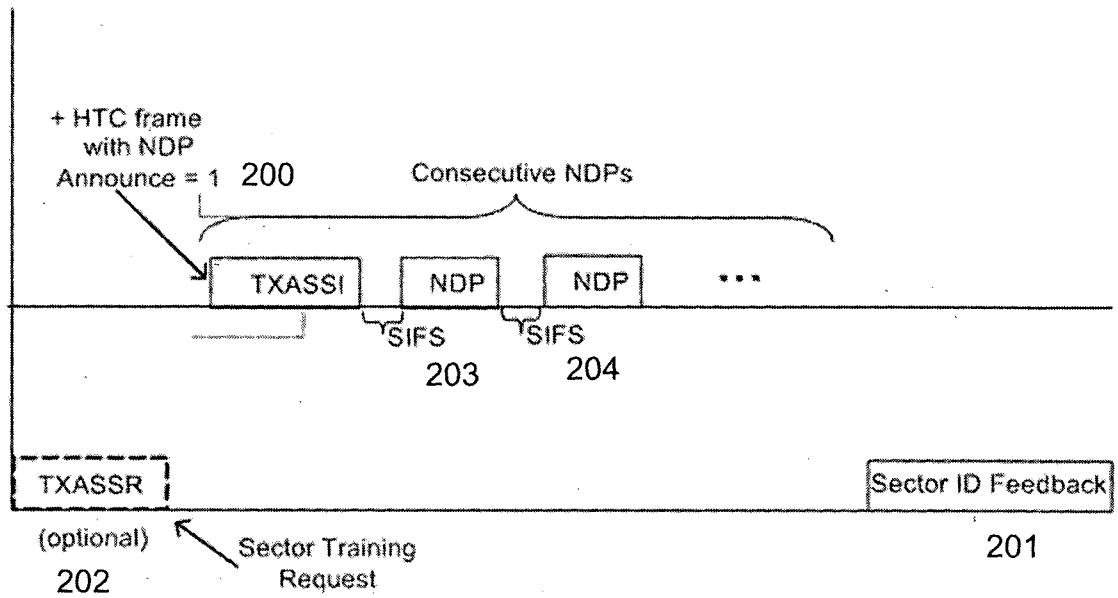

+ HTC frame
with NDP
Announce = 1
200
Consecutive NDPs
TXASSI
NDP
NDP
• • •
SIFS
SIFS
203
204
TXASSR
Sector ID Feedback
(optional)
202
Sector Training
Request
201

Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG2013/000289

A. CLASSIFICATION OF SUBJECT MATTER

H04B 7/04(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)
H04B 7/04; H04B 7/00; H04L 12/413; H04B 7/212; H04B 10/08; H04B 10/06; H04W 72/04; H04W 84/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: omni-beam duration, protection duration, sectorized beam, training frame

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2011-0128948 A1 (BEOM JIN JEON et al.) 02 June 2011 See paragraphs 16, 18, 43-45; and figures 3-4.	1,5
A		2-4,6-14
Y	US 2001-0006517 A1 (JIE LIN et al.) 05 July 2001 See paragraphs 3, 7-9; and figure 1.	1,5
A	US 2010-0150038 A1 (SANJIV NANDA et al.) 17 June 2010 See paragraphs 9, 81-84; and figure 10A.	1-14
A	US 2012-0082109 A1 (SEUNG EUN HONG et al.) 05 April 2012 See paragraphs 16, 41; and figure 3.	1-14
A	US 2012-0099856 A1 (DAVID BRITZ et al.) 26 April 2012 See paragraphs 16-17; and figures 1-2.	1-14

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

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 October 2013 (24.10.2013)	**25 October 2013 (25.10.2013)**

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INTERNATIONAL SEARCH REPORT

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