(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
7 August 2008 (07.08.2008)

PCT

(10) International Publication Number
WO 2008/094993 A1

(51) International Patent Classification:
H04Q 7/36 (2006.01)

(21) International Application Number:
PCT/US2008/052446

(22) International Filing Date: 30 January 2008 (30.01.2008)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

11/669,374	31 January 2007 (31.01.2007)	US
11/669,411	31 January 2007 (31.01.2007)	US
11/669,515	31 January 2007 (31.01.2007)	US
11/669,887	31 January 2007 (31.01.2007)	US

(71) **Applicant** *(for all designated States except US)*: **SYMBOL TECHNOLOGIES, INC.** [US/US]; One Symbol Plaza, Holtsville, NY 11742-1300 (US).

(72) **Inventors; and**
(75) **Inventors/Applicants** *(for US only)*: **LE, Vinh** [US/US]; 800 San Marco Avenue, Fremont, CA 94539 (US). **HINSZ, Chris** [US/US]; 693 Dotey Ct., San Jose, CA 95111 (US). **ZARRABIAN, Morteza** [US/US]; 265 Delphi Circle, Los Altos, CA 94022 (US).

(74) **Agent: POTE, Daniel**; Ingrassia Fisher & Lorenz, P.C., 7150 East Camelback Road, Suite 325, Scottsdale, AZ 85251 (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, BR, BW, BY, BZ, CA, CH, 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, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, 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, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) **Title:** METHODS AND APPARATUS FOR DETERMINING OPTIMAL RF TRANSMITTER PLACEMENT

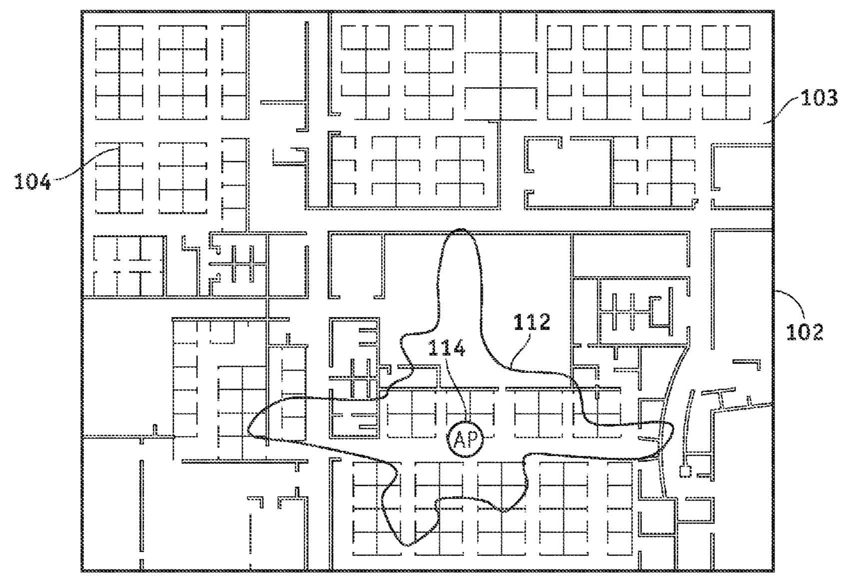

FIG. 1

(57) **Abstract:** Systems and methods are provided for optimizing the placement of RF components within an environment. The system operates by defining a spatial model associated with the environment, determining a first placement location of the RF device within the spatial model, determining a coverage area associated with the RF device, identifying a set of gaps associated with the coverage area, calculating a coverage metric based on the set of gaps, determining a second placement location of the RF device within the spatial model based on the coverage metric, and placing the AP in the second placement location within the environment if the coverage metric is less than or equal to a predetermined threshold.

WO 2008/094993 A1

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

INTERNATIONAL PATENT APPLICATION
Attorney Docket No.: 022.0041PC (2520PC)

METHODS AND APPARATUS FOR DETERMINING OPTIMAL RF TRANSMITTER PLACEMENT

TECHNICAL FIELD

[0001] The present invention relates to wireless local area networks (WLANs) and other networks incorporating RF elements and/or RF devices. More particularly, the present invention relates to methods for automating the placement of RF devices, such as access points, within an environment.

BACKGROUND

[0002] There has been a dramatic increase in demand for mobile connectivity solutions utilizing various wireless components and WLANs. This generally involves the use of wireless access points that communicate with mobile devices using one or more RF channels (e.g., in accordance with one or more of the IEEE 802.11 standards).

[0003] At the same time, RFID systems have achieved wide popularity in a number of applications, as they provide a cost-effective way to track the location of a large number of assets in real time. In large-scale applications such as warehouses, retail spaces, and the like, many RFID tags may exist in the environment. Likewise, multiple RFID readers are typically distributed throughout the space in the form of entryway readers, conveyer-belt readers, mobile readers, and the like, and these multiple components may be linked by network controller switches and other network elements.

[0004] Because many different RF transmitters and other components may exist in a particular environment, the deployment and management of such systems can be difficult and time-consuming. For example, it is desirable to configure access points and other such RF components such that RF coverage is complete within certain areas of the environment. Accordingly, there exist various RF planning systems that enable a user to predict indoor/outdoor RF coverage. The result is a prediction as to where the transmitters should be placed within the environment. Such systems are unsatisfactory in a number of respects, however, as they fall short of the requirements due to the presence of gaps and holes.

BRIEF SUMMARY

[0005] In general, systems and methods are provided for optimizing the placement of RF components (e.g., access points, access ports, RF antennas) within an environment. A method in accordance with one embodiment includes: defining a spatial model associated with the environment; determining a first placement location of the RF device within the spatial model; determining a coverage area associated with the RF device; identifying a set of gaps associated with the coverage area; calculating a coverage metric based on the set of gaps; determining a second placement location of the RF device within the spatial model based on the coverage metric; and placing the RF device in the second placement location within the environment if the coverage metric is less than or equal to a predetermined threshold.

[0006] This summary is provided to introduce a selection of concepts in a simplified form that are further described below in the detailed description. This summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] A more complete understanding of the present invention may be derived by referring to the detailed description and claims when considered in conjunction with the following figures, wherein like reference numbers refer to similar elements throughout the figures.

[0008] FIG. 1 is an example floor plan useful in depicting systems and methods in accordance with the present invention;

[0009] FIG. 2 is a conceptual top view of exemplary coverage areas for two RF transmitters in an environment;

[0010] FIGS. 3A and 3B depict the environment of FIG. 2 with changing location of a reference area; and

[0011] FIG. 4 is the environment of FIGS. 3A and 3B after relocation of the RF transmitters and redefinition of the reference area.

DETAILED DESCRIPTION

[0012] The present invention relates to a method for optimizing the placement of RF components within an environment to maximize RF coverage. In this regard, the following detailed description is merely illustrative in nature and is not intended to limit the embodiments of the invention or the application and uses of such embodiments. Furthermore, there is no intention to be bound by any expressed or implied theory presented in the preceding technical field, background, brief summary or the following detailed description.

[0013] Embodiments of the invention may be described herein in terms of functional and/or logical block components and various processing steps. It should be appreciated that such block components may be realized by any number of hardware, software, and/or firmware components configured to perform the specified functions. For example, an embodiment of the invention may employ various integrated circuit components, e.g., memory elements, digital signal processing elements, logic elements, look-up tables, or the like, which may carry out a variety of functions under the control of one or more microprocessors or other control devices. In addition, those skilled in the art will appreciate that embodiments of the present invention may be practiced in conjunction with any number of data transmission and data formatting protocols and that the system described herein is merely one example embodiment of the invention.

[0014] For the sake of brevity, conventional techniques related to signal processing, data transmission, signaling, network control, the 802.11 family of specifications, wireless networks, RFID systems and specifications, and other functional aspects of the systems (and the individual operating components of the systems) may not be described in detail herein. Furthermore, the connecting lines shown in the various figures contained herein are intended to represent example functional relationships and/or physical couplings between the various elements. It should be noted that many alternative or additional functional relationships or physical connections may be present in an embodiment of the invention.

[0015] The following description refers to elements or nodes or features being “connected” or “coupled” together. As used herein, unless expressly stated otherwise, “connected” means that one element/node/feature is directly joined to (or directly communicates with) another element/node/feature, and not necessarily mechanically. Likewise, unless expressly stated otherwise, “coupled” means that one element/node/feature is directly or indirectly joined to (or directly or indirectly communicates with) another element/node/feature, and not necessarily mechanically. The term “exemplary” is used in the sense of “example,” rather than “model.” Although the figures may depict example arrangements of elements, additional intervening elements, devices, features, or components may be present in an embodiment of the invention.

[0016] Referring to the conceptual plan view shown in FIG. 1, an access port or access point ("AP") 114 or other RF device is provided within an environment 103 defined by a boundary 102 (which may be indoors and/or outdoors). AP 114 has an associated RF coverage area (or simply "coverage") 112, which corresponds to the effective range of its antenna or RF transmitter, as described in further detail below. Various mobile units ("MUs") (not shown) may communicate with AP 114, which itself will typically be part of a larger network.

[0017] Environment 103, which may correspond to a workplace, a retail store, a home, a warehouse, or any other such space, will typically include various physical features 104 that affect the nature and/or strength of RF signals received and/or sent by AP 114. Such feature include, for example, architectural structures such as doors, windows, partitions, walls, ceilings, floors, machinery, lighting fixtures, and the like.

[0018] Boundary 102 may have any arbitrary geometric shape, and need not be rectangular as shown in the illustration. Indeed, boundary 102 may comprise multiple topologically unconnected spaces, and need not encompass the entire workplace in which AP 114 is deployed. Furthermore, the present invention is not limited to two-dimensional layouts; it may be extended to three dimensional spaces as well.

[0019] AP 114 is configured to wirelessly connect to one or more mobile units (MUs) (not shown) and communicate one or more switches, routers, or other networked components via appropriate communication lines (not shown). Any number of additional and/or intervening switches, routers, servers, and other network components may also be present in the system.

[0020] At any given time, 114 may have a number of associated MUs, and is typically capable of communicating with through multiple RF channels. This distribution of channels varies greatly by device, as well as country of operation. For example, in accordance with an 802.11(b) deployment there are fourteen overlapping, staggered channels, each centered 5 MHz apart in the RF band.

[0021] As described in further detail below, AP 114 includes hardware, software, and/or firmware capable of carrying out the functions described herein. Thus, AP may comprise one or more processors accompanied by storage units, displays, input/output devices, an operating system, database management software, networking software, and the like. Such systems are well known in the art, and need not be described in detail here.

[0022] For wireless data transport, AP 114 may support one or more wireless data communication protocols – e.g., RF; IrDA (infrared); Bluetooth; ZigBee (and other variants of the IEEE 802.15 protocol); IEEE 802.11 (any variation); IEEE 802.16 (WiMAX or any other variation); Direct Sequence Spread Spectrum; Frequency Hopping Spread Spectrum; cellular/wireless/cordless telecommunication protocols; wireless home network communication protocols; paging network protocols; magnetic induction; satellite data communication protocols; GPRS; and proprietary wireless data communication protocols such as variants of Wireless USB.

[0023] Referring now to FIG. 2, when multiple APs are positioned within boundary 102, various gaps or "holes" in coverage (or "coverage areas") may exist. For simplicity, the gaps are shown be two-dimensional; in actual applications they will have a three-dimensional nature. In a typical application, AP 114A may have been previously placed, and a new AP 114B is inserted to help with RF coverage. As illustrated, AP 114A has a corresponding coverage 112A, and AP 114B has a corresponding coverage 12B. These coverage areas may have any arbitrary shape or size, depending upon factors known in the art. For example, these coverage areas may be determined through a receiver signal strength indicator (RSSI) calculation, as is known in the art.

[0024] Coverage areas 112A-B, then, represent those areas within boundary 102 that can be expected to provide an acceptable level of service. This "acceptable" level of service may correspond to those regions wherein received signal levels are expected to reliably exceed a minimally-acceptable level (e.g. wherein the observed or predicted RSSI value exceeds an acceptable minimum value). Alternatively, other metrics of "acceptable" service could be used.

[0025] As shown, a gap 202 exists between coverage areas 112A and 112B, and a gap 204 exists between boundary 102 and the outer reaches of areas 112A and 112B. In accordance with the present invention, APs 114A and/or 114B are relocated to optimal positions based on a coverage metric, which may be iteratively recalculated adaptively until it reaches a predetermined coverage metric threshold (or simply "threshold").

[0026] The coverage metric may be any quantitative or qualitative measure of the gaps within an area at any given time. In one embodiment, for example, the coverage metric is equal to the total planar area of all gaps within the relevant area. The coverage metric may also take into account and assist with reducing overlapping coverage areas. In an alternate embodiment, the coverage metric may relate to how much RF coverage overlap can be allowed.

[0027] The coverage metric calculations are computed based on gaps in RF coverage present in the environment – which change size and/or position as the various APs 114 are moved to reduce the coverage metric within that area. In the illustrated embodiment, for example, two gaps are present: gap 202 and gap 302. Each of these gaps has planar geometrical attributes such as area, shape, centroid, and the like, all of which may be calculated (e.g., using suitable hardware and software) given the shapes of coverage areas 112. Reference area 304 is shown as rectangular; however, the present invention is not so limited. In the event reference area 304 is rectangular, it is desirable to define one or more corners of area 304 such that those corners correspond to the location of one or more APs 114 (e.g., a previously-placed AP). Alternatively, reference area 304 may be defined based on the position of other system components as well as barriers and the like.

[0028] Operation of the system generally proceeds as follows. First, modeling information regarding the environment and components within the environment 103 are collected to produce a spatial model. This information may include, for example, building size and layout, country code, transmit power per AP, antenna gain, placement constraints, transmit power constraints, data rate requirements, coverage requirements, barrier information, and the like.

[0029] The size and shape of the coverage areas 112 within boundary 102 are then determined for the set of APs 114. Next, any contiguous gaps (e.g., gaps 202 and 302) within environment 103 are identified, and the shape, size, and any other suitable attributes for those gaps is computed. The coverage metric is then computed, based, for example, on the total area of gaps 202 and 302.

[0030] In one embodiment, the very first time the algorithm starts, AP 114A will take an initial position as shown in FIG. 3A. The initial position of AP 114A is computed based upon a suitable formula constrained by RF coverage requirements. The size and shape of the coverage areas 112 within boundary 102 are then determined for AP 114A. In this embodiment, a reference area 305 is formed by the AP (x,y) coordinate, the leftmost outer wall of boundary 102, and the bottom outer wall of boundary 102. An optimization process is then performed to determine the best location for AP 114A. At each iteration of the process, AP114A might have a new (x,y) coordinate but the reference area 305 definition with respect to the whole graph remains the same. Next, any contiguous gaps within reference area 305 are identified, and the shape, size, and any other suitable attributes for those gaps are computed. The coverage metric is then computed for reference area 305, based, for example, on the total area of the gap 205.

[0031] When AP114a has settled into its final position, a new AP is suitably added, as shown in FIG. 3B. In this example, AP 114B is the second AP to be added. Again, AP

114A will take a general initial position as shown. However, in a different variation of the implementation, the position of the next -- e.g. second -- AP might have a special relationship with the last AP. That is, the next AP initial position might take the same y coordinate as the last AP, while the x coordinate is derived computationally. In either case, a new reference area 306 is formed by the second AP (x,y) coordinate and the same outer wall of the graphs as the previous case. The optimization process is again initiated for the second AP based only upon reference area 306. In an alternate example, the reference area 306 may be a rectangle with two corners bounded by the two APs 114A and 114B. This technique can be used to greatly reduce computation time.

[0032] Once the coverage metric is computed, the system determines a new position for one or more of the APs – e.g., the most recent AP to enter the environment. Next, the AP (e.g., AP 114B) is moved within the spatial model to that new position. The new position may be determined by defining an angular direction in which the AP should move, as well as a step size (i.e., distance) that defines the scalar distance. The step size may be selected in accordance with known principles to achieve the desired stability and convergence time.

[0033] The direction (e.g., angular direction) of AP movement during an iteration may be specified in any suitable manner based on gap locations. In one embodiment, an average gap metric is computed based on an integration or discrete summation of the distances from the AP to points within a gap. The angular direction may correspond a line leading from the current placement of the AP to an extrema (i.e., a point on the perimeter) of one of the gaps. In a particular embodiment, the angular direction is defined by the point on the perimeter of the gap that is farthest away from the current position of the AP. In this regard, the environment may be discretized into a grid for computational purposes.

[0034] Referring again to FIG. 2, the further extrema of gap 202 from APs 114A-B are points 252 and 258, respectively. By drawing conceptual lines between APs 114A-B and respective points 252 and 258, two possible movement vectors 254, 256 can be identified. Each of these vectors 254, 256 can be conceptually represented with an angle (θ) to the horizontal, vertical or other appropriate reference, as well as a scalar magnitude. FIG. 2, for example, shows two angles θ_1 and θ_2 representing potential directions of movement for APs 114A and 114B, respectively. Other embodiments may define direction of movement based upon a centroid or "center of mass" calculation related to the gap, or upon any other factor(s).

[0035] The distance that the AP is moved may be selected in accordance with any of various principles to achieve the desired stability and convergence time. In various embodiments, the distance is based upon the size of the gap or the distance from the AP to the gap. In various embodiments, an average gap metric can be computed based on an integration or discrete summation of the distances from the AP to one or more points within a gap. This summation may be based upon the entire area of the gap, or may be limited to the points located on the periphery of the gap. In still other embodiments, an average hole size ("W") of all the gaps present within environment 103 may be computed, and the step size can be determined based upon this quantity. Such embodiments may thereby base the distance moved on the relative size of the hole of interest with respect to the total area of holes to be eliminated, thereby potentially reducing deleterious effects upon other holes within environment 103. The distance may also be adjusted based upon building materials, objects in the vector path and/or other factors as appropriate.

[0036] After the direction and distance of vector 254 or 256 is conceptualized, the corresponding AP 114A or 114B can be moved accordingly. Although FIG. 2 shows a potential vector for each of APs 114A-B, in practice only one AP needs to be moved during any particular iteration of the placement process. After the subject AP has been relocated, the system again determines the size and shape of the coverage areas and recomputes the coverage metric. If the coverage metric is equal to or less than a predefined threshold, the system once again computes a new position for one or more of the APs, and the process continues as before until the predefined threshold is reached or it is determined that the process should otherwise stop (e.g., due to the non-existence of a solution, non-convergence, or a time out event). The predefined threshold may be selected to achieve any particular design objective – e.g., the coverage metric value corresponding to the minimum signal level in which a certain data rate can operate.

[0037] After the subject AP has been relocated, the system again determines the size and shape of the coverage areas and recomputes the coverage metric. If the coverage metric is equal to or less than a predefined threshold, the system once again computes a new position for one or more of the APs, and the process continues as before until the predefined threshold is reached or it is determined that the process should otherwise stop (e.g., due to the non-existence of a solution, non-convergence, or a time out event). The predefined threshold may be selected to achieve any particular design objective – e.g., the coverage metric value corresponding to the minimum signal level in which a certain data rate can operate.

[0038] FIG. 4 shows the example of FIG. 3B after relocation of AP 114B. As depicted, the gaps 202 and 302 of FIG. 3 have been eliminated or substantially eliminated such that the coverage metric within the previously-defined reference area are within the predefined threshold, and a new reference area 304 has been defined for the purposes of further adaptively improving coverage. The shape and size of coverage areas 112A and 112B have changed accordingly, resulting in two gaps 402 and 404 within reference area 304. The system may the proceed to improve coverage either by moving AP 114A or 114B, or adding a new AP within boundary 102.

[0039] In various embodiments, the grid or other quantized data abstraction mentioned above may be used to assist in initial placement of RF transmitters. According to one exemplary technique, the first transmitter may be placed with reference to a corner or other point of reference within environment 103. FIG. 3A shows AP 114A placed within environment 103 at a location having coordinates (X', Y') as determined with respect to corner 352; in equivalent embodiments, other corners or points within environment 103 could be used as a starting reference point. The initial values of X' and Y' could be selected as any default value (including zero), as any value determined with respect to the size of environment 103 (e.g. determined from a midpoint, quarter-point or other position related to the horizontal, vertical and/or lateral length of environment 103), or according to any other technique. In some embodiments, the initial values may be computed as any function of AP transmit power, threshold RSSI, data transmit frequency, and/or any other RF factors as appropriate. One formula that could be used, for example, relates the initial distance (D) from a corner of the environment to various RF factors as follows:

$$D = 10^{\frac{(P_{TX} - RSSI + 37 - 20\log_{10}(f))}{20}}$$

wherein "PTX" is the transmitter power in dBm, RSSI is the threshold acceptable signal strength in dBm, and *f* is the transmit frequency in megahertz. The resulting value for "D" is expressed in feet (but is readily convertible to meters by simply multiplying by 0.3048). Of course the particular values shown in the equation will vary based upon the particular environment, system of measurement, and other factors. Many embodiments may similarly modify the relationship shown in the formula to adjust for building materials, presence or absence of barriers, transmitter or receiver characteristics, and/or other factors as appropriate. Further, it is assumed in this example that the distance "D" could provide a suitable starting coordinate in both the "X" and "Y" directions shown in FIG. 2 (that is, "X'" and "Y'" are initially assumed to be equal). This relation need not hold true in other embodiments, and different formulas for computing initial values of X' and Y' could be used in other embodiments. Still further, it is assumed that the initial value of both X' and Y' lie within acceptable positions in environment 103. Through simple checking of coordinates, these starting values may be adjusted if they are found to place the transmitter at an undesirable location (e.g. a stairwell, restroom or the like) or if the determined values (e.g. the values resulting from the equation above) result in a location outside of environment 103. Such adjustment may be resolved by simply modifying the X and/or Y coordinate until the issue is removed, by dividing the computed value by any appropriate scaling constant (e.g. by two), or by any other adjusting technique.

[0040] After initial placement, the size and shape of the coverage areas 112 within boundary 102 may then be determined for AP 114A, using any appropriate technique. In the embodiment shown in FIG. 3A, for example, a reference area 305 can be formed by the AP (x,y) coordinate, the leftmost outer wall of boundary 102, and the bottom outer wall of boundary 102. An optimization process is then performed to determine the best location for AP 114A. At each iteration of the process, AP114A might have a new (x,y) coordinate but the reference area 305 definition with respect to the whole graph remains the same. Next, any contiguous gaps within reference area 305 are identified, and the shape, size, and any other suitable attributes for those gaps are computed. The coverage metric is then computed for reference area 305, based, for example, on the total area of the gap 205.

[0041] At any appropriate time (e.g. when AP 114A has settled into its final position), a new AP is suitably added, as shown in FIG. 3B. In this example, AP 114B is the second AP to be added. Again, AP 114A will take a general initial position as shown. However, in a different variation of the implementation, the position of the next -- e.g. second -- AP might have a special relationship with the last AP. That is, the next AP initial position might take the same y coordinate as the last AP, while the x coordinate is derived computationally. In either case, a new reference area 306 is formed by the second AP (x, y) coordinate and the same outer wall of the graphs as the previous case. The optimization process is again initiated for the second AP based only upon reference area 306. In an alternate example, the reference area 306 may be a rectangle with two corners bounded by the two APs 114A and 114B. This technique can be used to greatly reduce computation time.

[0042] APs 114A-B may be initially and subsequently placed according to any technique. In various embodiments, the number of APs is initially estimated (either automatically or by the user), with the positions of APs initially determined using any of the techniques described above. In various embodiments, the first transmitter is initially placed using the techniques described above, and then processing continues to process rows and/or columns across environment 103 using the conceptual grid as appropriate. That is, each row can be analyzed until a gap in coverage is identified, and then an additional transmitter is placed at the same column coordinate as the previous transmitter until the row is filled. Processing then continues with the next unfilled row until the corner opposite the starting point 352 is reached. Of course columnar processing could be readily substituted for row processing, or any other coordinate system (including angular coordinates based upon angular position and radius from a starting point) could be used in any number of equivalent embodiments. In another variation of this implementation, the system might arrange the second row (or column) of APs to be in a staggered position with respect to the previous row (or column) for the purpose of further reducing the cluster effects. That is, the first and second coordinates of each of the plurality of RF devices are determined to create a staggered pattern with respect to the position of the other RF devices.

[0043] In such embodiments, the two transmitters might not share common X or Y coordinates, but the second transmitter (e.g. AP 114B) could still be considered to be placed with respect to the position of the first transmitter (e.g. AP 114A). APs 114A-B need not be initially placed in linear fashion with each other, then, but may be determined according to any pre-determined placement technique based upon, for example, the relative positions of the transmitters.

[0044] The methods described above may be performed in hardware, software, or a combination thereof. For example, in one embodiment one or more software modules are configured to be executed on a general purpose computer having a processor, memory, I/O, display, and the like.

[0045] While at least one example embodiment has been presented in the foregoing detailed description, it should be appreciated that a vast number of variations exist. It should also be appreciated that the example embodiment or embodiments described herein are not intended to limit the scope, applicability, or configuration of the invention in any way. Rather, the foregoing detailed description will provide those skilled in the art with a convenient road map for implementing the described embodiment or embodiments. It should be understood that various changes can be made in the function and arrangement of elements without departing from the scope of the invention, where the scope of the invention is defined by the claims, which includes known equivalents and foreseeable equivalents at the time of filing this patent application.

CLAIMS

What is claimed is:

1. A method of positioning an RF device within an environment, comprising the steps of:

defining a spatial model associated with the environment;

determining a first placement location of the RF device within the spatial model;

determining a coverage area associated with the RF device;

identifying a set of gaps associated with the coverage area;

calculating a coverage metric based on the set of gaps;

determining a second placement location of the RF device within the spatial model based on the coverage metric;

calculating a second coverage metric based on a second set of gaps; and

placing the RF device in the second placement location within the environment if the second coverage metric is less than or equal to a predetermined threshold value.

2. The method of claim 1, further including repeating the step of identifying the set of gaps when the coverage metric is greater than the predetermined threshold.

3. The method of claim 1, wherein the coverage metric is based on the area of the set of gaps.

4. The method of claim 3, wherein the coverage metric includes a measure of overlap associated with coverage area.

5. The method of claim 1, wherein determining the coverage area associated with the RF device includes performing an RSSI calculation.

6. The method of claim 1, wherein defining the spatial model includes determining the location of one or more barriers within the environment.

7. A system for positioning an RF device within an environment, comprising:

a processor configured to accept a spatial model associated with the environment, determine a first placement location of the RF device within the spatial model, determine a coverage area associated with the RF device, identify a set of gaps associated with the coverage area, calculate a first coverage metric based on the set of gaps, determine a second placement location of the RF device within the spatial model based on the second coverage metric, and compare the second coverage metric to a predetermined threshold; and

a display for displaying the spatial model and the second placement location.

8. The system of claim 7, wherein the processor computes the coverage metric based on the area of the set of gaps.

9. The system of claim 8, wherein the processor computes the coverage metric based in part on overlap associated with the coverage area.

10. The system of claim 7, wherein the processor computes the coverage area associated with the RF device by performing an RSSI calculation.

11. The system of claim 7, wherein the spatial model includes the location of one or more barriers within the environment.

12. The system of claim 7, wherein the RF device is a wireless access point.

13. The system of claim 12, wherein the wireless access point conforms to a 802.11 specification.

14. A method of positioning an RF device within an environment, comprising the steps of:

defining a spatial model associated with the environment;

determining a first placement location of the RF device within the spatial model;

determining a coverage area associated with the RF device;

defining a reference area within the environment;

identifying a set of gaps associated with the coverage area within the reference area;

determining a second placement location of the RF device within the spatial model based on the set of gaps;

identifying a second set of gaps within the reference area; and

placing the RF device in the second placement location based on the second set of gaps.

15. The method of claim 14, further including computing a coverage metric based on the set of gaps, and repeating the step of identifying the set of gaps within when the coverage metric is greater than a predetermined threshold.

16. The method of claim 14, wherein the reference area is rectangular.

17. The method of claim 16, wherein the reference area has at least one corner corresponding to the location of the RF device.

18. A system for positioning an RF device within an environment, comprising:

a processor configured to accept a spatial model associated with the environment, determine a first placement location of the RF device within the spatial model, determine a coverage area associated with the RF device, determine a reference area, identify a set of gaps associated with the coverage area within the reference area, determine a second placement location of the RF device within the spatial model based on the set of gaps, identify a second set of gaps within the reference area, and determine an optimum position based on the second set of gaps;

a display for displaying the spatial model and the second placement location.

19. The system of claim 18, wherein the processor is further configured to compute a coverage metric based on the area of the set of gaps.

20. A method of positioning a plurality of RF devices each having a position and a coverage area within an environment, the method comprising the steps of:

identifying a gap in the environment that is outside the coverage areas of the plurality of RF devices;

computing a size of the gap and a relative direction of the gap from the position of one of the plurality of RF devices; and moving the position of the one of the plurality of RF devices in a direction corresponding to the relative direction to thereby reduce the size of the gap.

21. The method of claim 20 wherein the moving step comprises moving the position of the one of the plurality of RF devices a distance determined at least in part upon the size of the gap.

22. The method of claim 21 wherein the gap is one of a plurality of gaps and the distance is further determined as a function of an average size of the plurality of gaps.

23. A method of positioning a plurality of RF devices each providing a coverage area within an environment, the method comprising the steps of:

defining a spatial model associated with the environment and comprising a reference point;

initially placing a first one of the plurality of RF devices at a first initial location within the spatial model, wherein the first initial location is determined with respect to the reference point;

determining the coverage area for the first RF device;

initially placing a second one of the plurality of RF devices at a second initial location within the spatial model, wherein the second initial location is determined with respect to the coverage area of the first RF device; and

adjusting at least one of the first and second initial locations to improve the combined coverage area of the first and second RF devices.

24. The method of claim 23 wherein the first initial location is determined to be a computed distance from the reference point.

25. The method of claim 23 wherein the spatial model comprises a first coordinate and a second coordinate, and wherein the first and second initial locations are defined by values of the first and second coordinates.

26. The method of claim 25 wherein the second initial position comprises either a first coordinate value or a second coordinate value that is substantially equal to that of the first initial position.

27. The method of claim 25 wherein the first and second coordinates of each of the plurality of RF devices are determined to create a staggered pattern with respect to the position of the other RF devices.

28. The method of claim 24 wherein the computed distance (D) is computed based at least in part upon the following relationship:

$$D = 10^{\frac{(P_{TX} - RSSI + 37 - 20\log_{10}(f))}{20}}$$

wherein P_{TX} is the transmitter power in dBm, RSSI is the threshold acceptable signal strength in dBm, and f is the transmit frequency in megahertz.

29. The method of claim 24 wherein the value of at least one of the two coordinates for the first initial position is computed based upon the following relationship:

$$D = 10^{\frac{(P_{TX} - RSSI + 37 - 20\log_{10}(f))}{20}}$$

wherein D is the value of the at least one of the two coordinates, P_{TX} is the transmitter power in dBm, RSSI is the threshold acceptable signal strength in dBm, and f is the transmit frequency in megahertz.

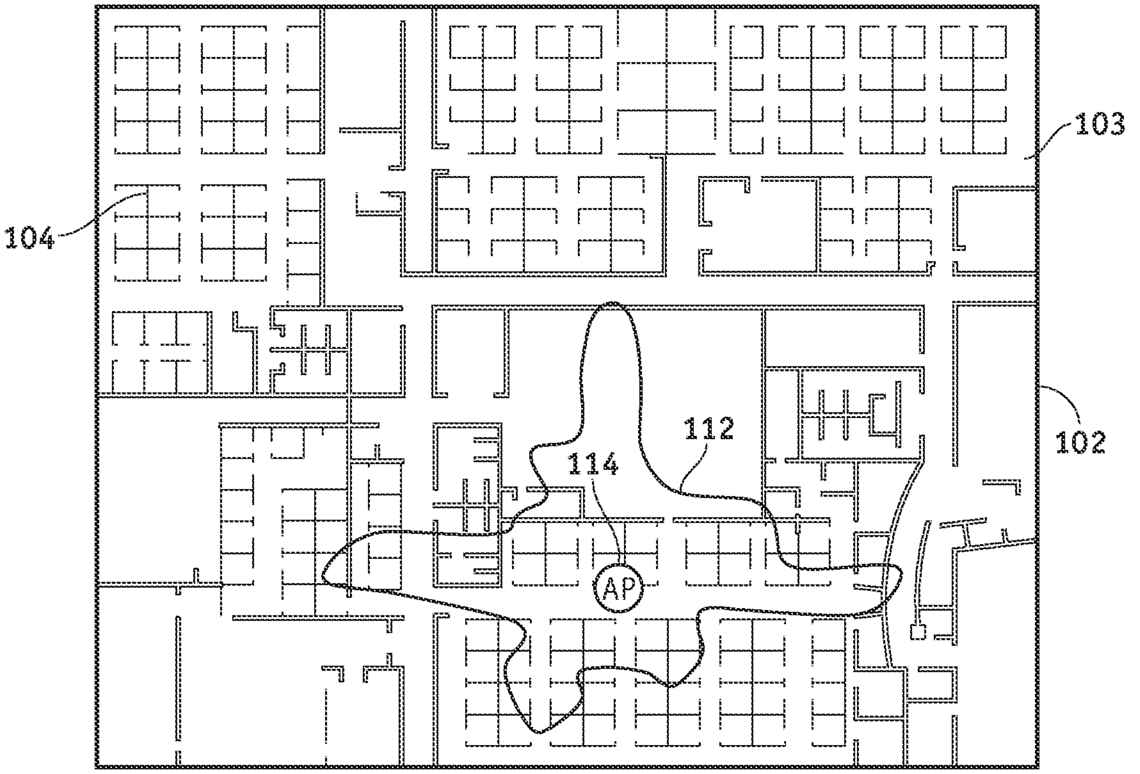

FIG. 1

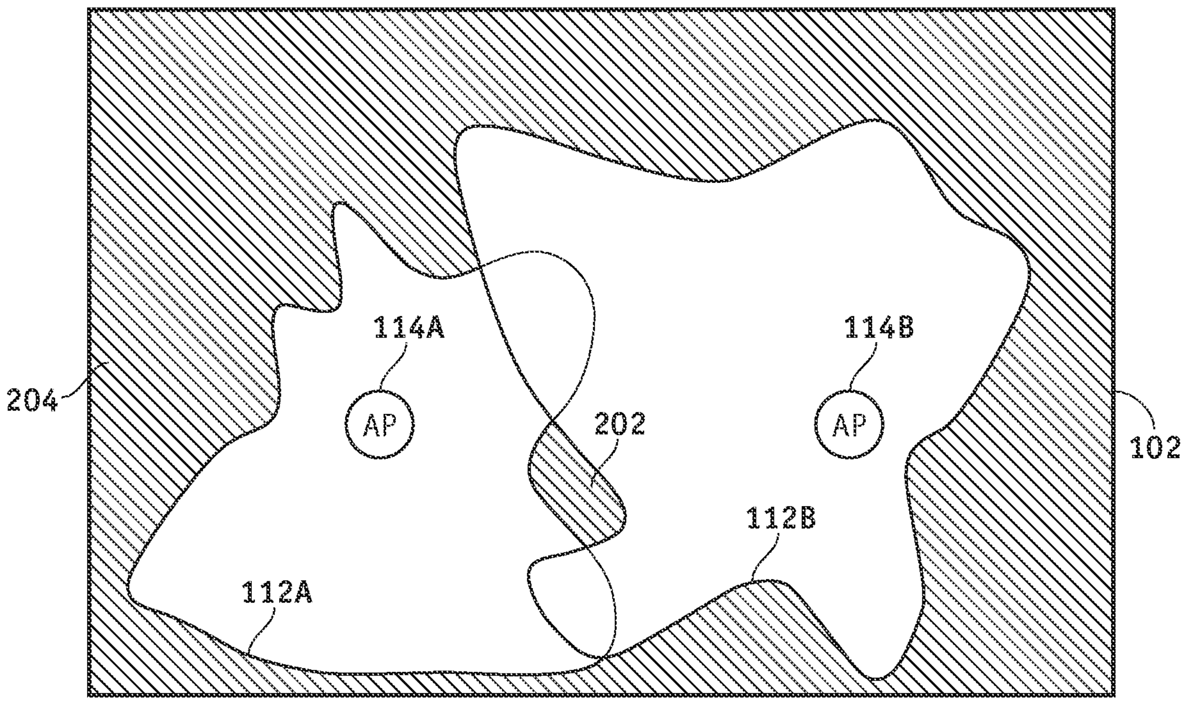

FIG. 2

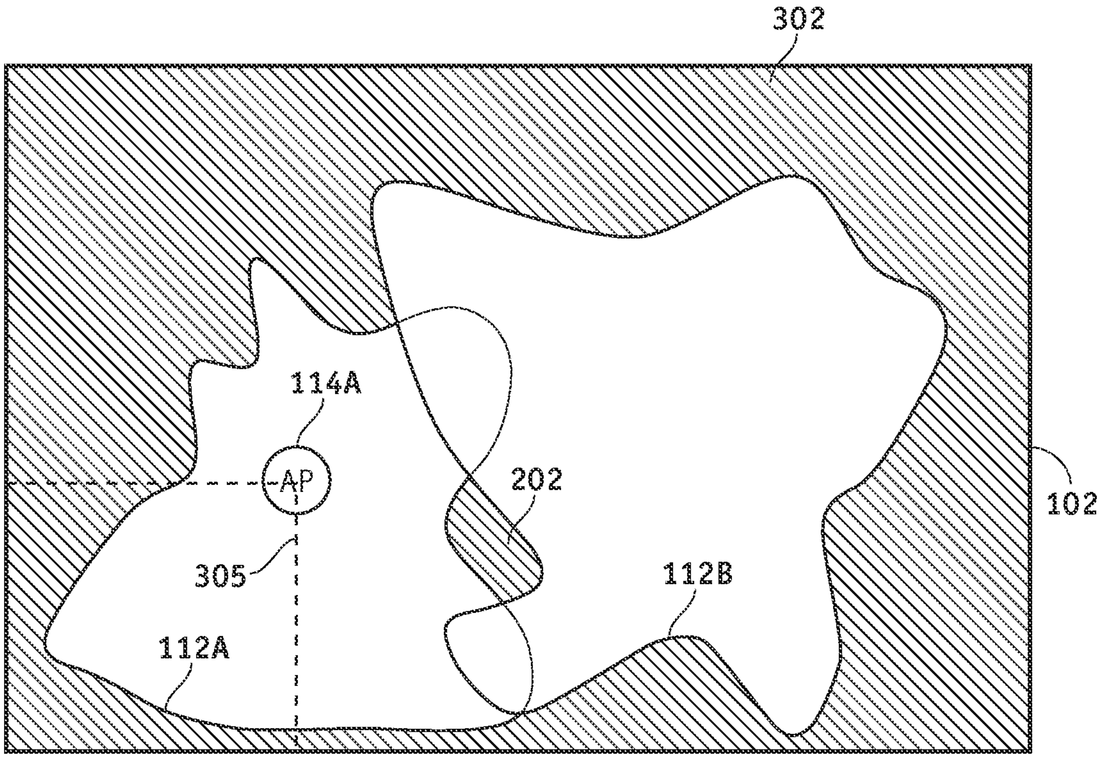
302
114A
AP
202
102
305
112B
112A

FIG. 3A

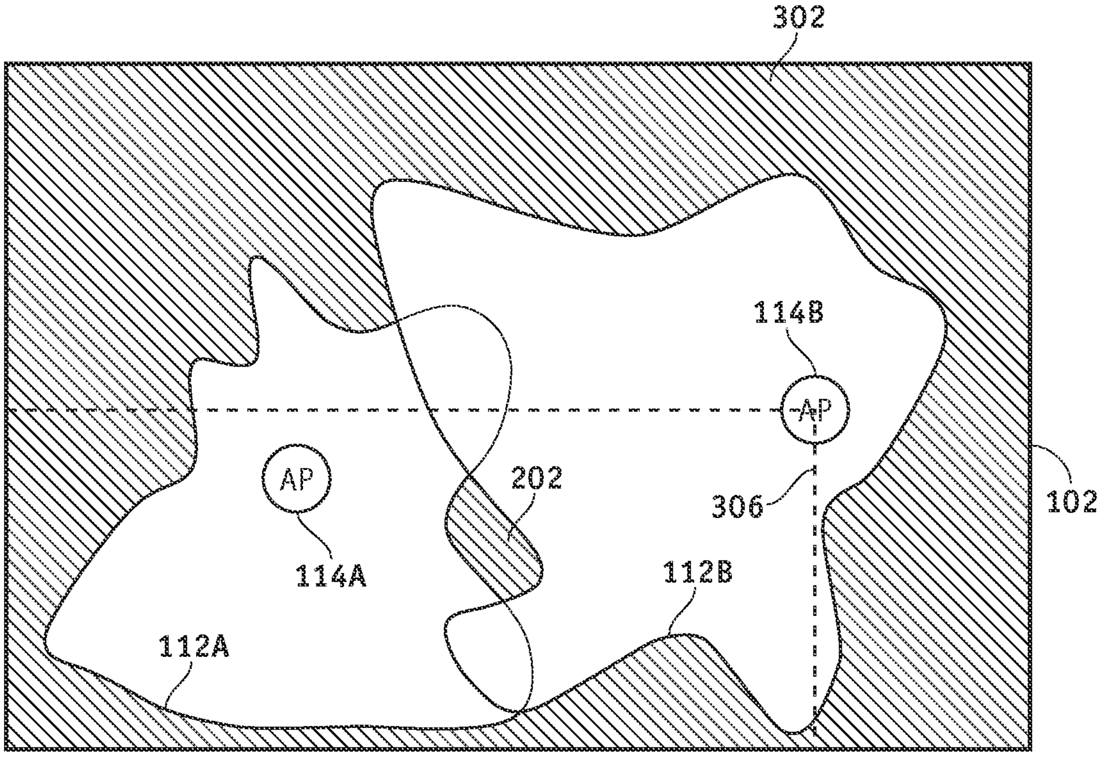
302
114B
AP
AP
202
102
306
114A
112B
112A

FIG. 3B

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2008/052446

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04Q7/36

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)
H04Q

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 practical, search terms used)

EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 01/78327 A (UNIV CARNEGIE MELLON [US]) 18 October 2001 (2001-10-18) page 1, line 23 - line 26 page 5, line 20 - page 8, line 10 -----	1-13
X	US 2006/002326 A1 (VESUNA SAROSH [US]) 5 January 2006 (2006-01-05) page 1, paragraph 4 page 2, paragraph 8 page 2, paragraph 11 page 3, paragraph 23 -----	1-13
X	US 2005/059405 A1 (THOMSON ALLAN [US] ET AL) 17 March 2005 (2005-03-17) page 1, paragraph 8 - paragraph 11 page 2, paragraph 18 page 2, paragraph 21 page 3, paragraph 23 - paragraph 29 -----	1-13

☐ 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

"E" earlier document 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	Date of mailing of the international search report
26 June 2008	04/07/2008

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Garcia, Montse

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box II.2

Claims Nos.: 14-27

An incomplete search report has been established for claims 14-27 because these claims failed to comply with the prescribed requirements to such an extend that a meaninful search could not be carried out (Art. 17(2)(b) PCT).

In particular these claims contain subject-matter which is not clear. It is not possible to look for support in the description in order to interpret said claims together as most of references to figures 2, 3A and 3B and fig 4 are missing.

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guideline C-VI, 8.2), should the problems which led to the Article 17(2)PCT declaration be overcome.

INTERNATIONAL SEARCH REPORT	International application No. PCT/US2008/052446

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.: 14-27
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:
see FURTHER INFORMATION sheet PCT/ISA/210

3. ☐ Claims Nos.:
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 allsearchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an 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 reportcovers 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.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2008/052446

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
WO 0178327	A	18-10-2001	AU	5699301	A	23-10-2001
			US	6711148	B1	23-03-2004
US 2006002326	A1	05-01-2006	CN	101057157	A	17-10-2007
			EP	1761796	A2	14-03-2007
			JP	2008505541	T	21-02-2008
			WO	2006004628	A2	12-01-2006
US 2005059405	A1	17-03-2005	CA	2538331	A1	24-03-2005
			EP	1665837	A2	07-06-2006
			JP	2007506376	T	15-03-2007
			WO	2005027393	A2	24-03-2005