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(71) Applicant: **EXTRICOM LTD.** [IL/IL]; Beit Schema, Kibbutz Glil Yam, 46905 Herzlia (IL).

(72) Inventor: **SHPAK, Eran**; 5 Pineless Street, 62265 Tel Aviv (IL).

(74) Agents: **SANFORD T. COLB & CO.** et al.; P.O. Box 2273, 76122 Rehovot (IL).

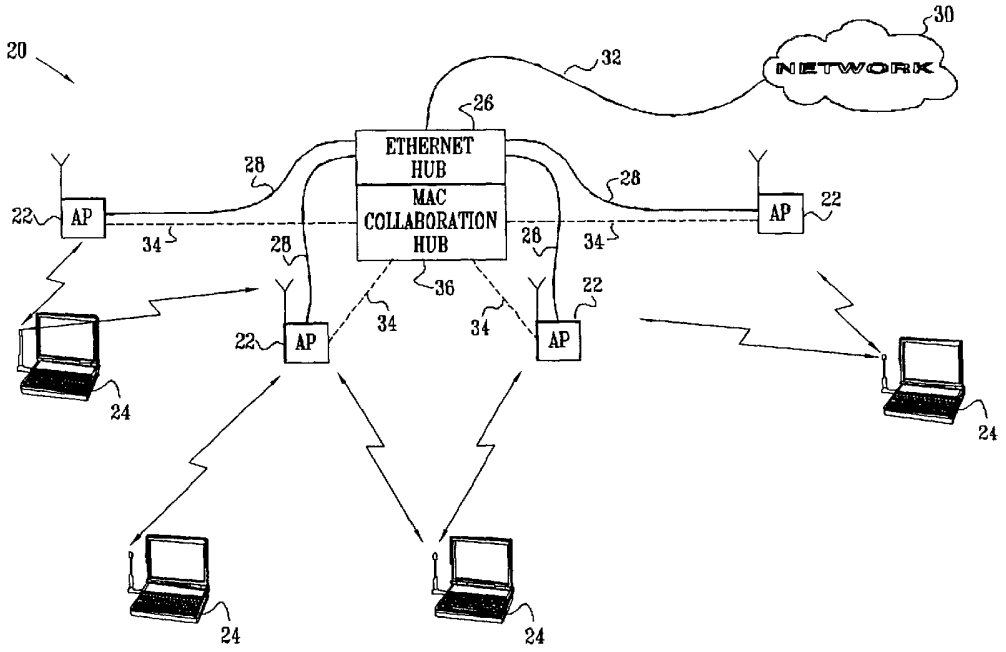
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(54) **Title:** COLLABORATION BETWEEN WIRELESS LAN ACCESS POINTS



(57) **Abstract:** A method for mobile communication includes arranging a plurality of access points (22) in a wireless local area network (WLAN) to communicate on a common frequency channel with a mobile station (24). Upon receiving at one or more of the access points an uplink signal transmitted over the WLAN by the mobile station on the common frequency channel, the access points receiving the uplink signal arbitrate among themselves so as to select one of the access points to respond to the uplink signal. A response is then transmitted from the selected one of the access points to the mobile station.

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COLLABORATION BETWEEN WIRELESS LAN ACCESS POINTS

FIELD OF THE INVENTION

The present invention relates generally to wireless communications, and specifically to methods and devices for improving the performance of wireless local area networks.

BACKGROUND OF THE INVENTION

Wireless local area networks (WLANs) are gaining in popularity, and new wireless applications are being developed. The original WLAN standards, such as "Bluetooth" and IEEE 802.11, were designed to enable communications at 1-2 Mbps in a band around 2.4 GHz. More recently, IEEE working groups have defined the 802.11a, 802.11b and 802.11g extensions to the original standard, in order to enable higher data rates. The 802.11a standard, for example, envisions data rates up to 54 Mbps over short distances in a 5 GHz band, while 802.11b defines data rates up to 22 Mbps in the 2.4 GHz band. In the context of the present patent application and in the claims, the term "802.11" is used to refer collectively to the original IEEE 802.11 standard and all its variants and extensions, unless specifically noted otherwise.

The theoretical capability of new WLAN technologies to offer enormous communication bandwidth to mobile users is severely hampered by the practical limitations of wireless communications. Indoor propagation of radio frequencies is not isotropic, because radio waves are influenced by building layout and furnishings. Therefore, even when wireless access points are carefully positioned throughout a building, some "black holes" generally remain - areas with little or no radio reception. Furthermore, 802.11 wireless links can operate at full speed only under conditions of high signal/noise ratio. Signal strength scales inversely with the distance of the mobile station from its access point, and therefore so does communication speed. A single mobile station with poor reception due to distance or radio propagation problems can slow down WLAN access for all other users in its basic service set (BSS - the group of mobile stations communicating with the same access point).

The natural response to these practical difficulties would be to distribute a greater number of access points within the area to be served. If a receiver receives signals simultaneously from two sources of similar strength on the same frequency channel, however, it is generally unable to decipher either signal. The 802.11 standard provides a mechanism for

collision avoidance known as clear channel assessment (CCA), which requires a station to refrain from transmitting when it senses other transmissions on its frequency channel. In practice, this mechanism is of limited utility and can place a heavy burden on different BSSs operating on the same frequency channel.

Therefore, in 802.11 WLANs known in the art, access points in mutual proximity must use different frequency channels. Theoretically, the 802.11b and 802.11g standards define 14 frequency channels in the 2.4 GHz band, but because of bandwidth and regulatory limitations, WLANs operating according to these standards in the United States actually have only three different frequency channels from which to choose. (In other countries, such as Spain, France and Japan, only one channel is available.) As a result, in complex, indoor environments, it becomes practically impossible to distribute wireless access points closely enough to give strong signals throughout the environment without substantial overlap in the coverage areas of different access points operating on the same frequency channel.

SUMMARY OF THE INVENTION

It is an object of some aspects of the present invention to provide methods and devices for enhancing the coverage and speed of WLAN systems.

In preferred embodiments of the present invention, a WLAN system comprises multiple wireless access points distributed within a service region. In order to provide complete coverage of the service region, with strong communication signals throughout the region, the access points are preferably closely spaced, and their areas of coverage may substantially overlap one another. In order to deal with this overlap, the access points communicate among themselves using a novel protocol over a high-speed, low-latency communication medium. Preferably, the medium comprises a dedicated wire or fiberoptic network, but wireless media may also be used for this purpose.

When a mobile station sends an uplink message attempting to initiate communications in a given frequency channel, a number of access points operating in this frequency channel may typically receive the message. These access points arbitrate among themselves by communicating over the dedicated medium, in order to decide which of the access points will communicate with this mobile station. This arbitration process is preferably repeated each time a mobile station in the WLAN service region sends a new uplink message. Problems of overlapping coverage areas and collisions are thus resolved, typically in favor of the access point that is closest to the mobile station in question. The access points may therefore be

deployed within the service region as closely as desired, so that mobile stations everywhere in the service region experience good radio coverage, without "black holes," and can operate at optimal speed.

There is therefore provided, in accordance with a preferred embodiment of the present invention, a method for mobile communication, including:

arranging a plurality of access points in a wireless local area network (WLAN) to communicate on a common frequency channel with a mobile station;

receiving at one or more of the access points an uplink signal transmitted over the WLAN by the mobile station on the common frequency channel;

arbitrating among the access points receiving the uplink signal so as to select one of the access points to respond to the uplink signal; and

transmitting a response from the selected one of the access points to the mobile station.

Typically, the access points have respective service areas, and arranging the plurality of the access points includes arranging the access points so that the service areas substantially overlap.

In a preferred embodiment, arranging the plurality of the access points includes arranging the access points to communicate with the mobile station substantially in accordance with IEEE Standard 802.11. Preferably, arbitrating among the access points includes selecting the one of the access points to respond to the uplink signal within a time limit imposed by the IEEE Standard 802.11 for acknowledging the uplink signal.

Preferably, arbitrating among the access points includes sending messages over a shared communication medium linking the access points, wherein sending the messages includes sending broadcast messages from the access points receiving the uplink signal to the plurality of the access points. Further preferably, sending the broadcast messages includes sending the messages over the shared communication medium from two or more of the access points simultaneously using a multiple access protocol. Most preferably, the multiple access protocol includes a code division multiple access (CDMA) protocol.

Alternatively or additionally, arbitrating among the access points includes receiving and processing the messages at each of the plurality of the access points, so that each of the access points determines which one of the access points is to be selected to respond to the uplink signal. Typically, processing the messages includes selecting, responsive to the messages, the one of the access points that was first to receive the uplink signal. Alternatively

or additionally, sending the messages includes indicating in the messages a strength of the uplink signal received by each of the access points.

In a preferred embodiment, arranging the plurality of the access points includes linking the access points in a local area network (LAN) for conveying data to and from the mobile station, the LAN including a cable having multiple conductors, and sending the messages includes passing the messages over one or more of the conductors on the cable that are not used for conveying the data to and from the mobile station.

There is also provided, in accordance with a preferred embodiment of the present invention, a system for mobile communication, including:

a communication medium; and

a plurality of access points interconnected by the medium and arranged in a wireless local area network (WLAN) to communicate on a common frequency channel with a mobile station, the access points being adapted, upon receiving at one or more of the access points an uplink signal transmitted over the WLAN by the mobile station on the common frequency channel, to arbitrate among the access points receiving the uplink signal by sending messages over the medium so as to select one of the access points to respond to the uplink signal, and to transmit a response from the selected one of the access points to the mobile station.

There is additionally provided, in accordance with a preferred embodiment of the present invention, access point apparatus for deployment in a wireless local area network (WLAN) as one of a plurality of access points for mobile communication, the apparatus including:

a radio transceiver, which is configured to communicate on a predetermined frequency channel with a mobile station; and

a message processor, which is adapted, when the transceiver receives an uplink signal transmitted over the WLAN by the mobile station on the predetermined frequency channel, to carry out an arbitration protocol together with others of the access points receiving the uplink signal so as to select one of the access points to respond to the uplink signal, and to control the transceiver so that the transceiver returns a response to the mobile station subject to the arbitration protocol.

The present invention will be more fully understood from the following detailed description of the preferred embodiments thereof, taken together with the drawings in which:

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram that schematically illustrates a WLAN system, in accordance with a preferred embodiment of the present invention;

Fig. 2 is a schematic illustration of a mobile station communicating with multiple wireless access points, in accordance with a preferred embodiment of the present invention;

Fig. 3 is a flow chart that schematically illustrates a method for establishing a communication link between a mobile station and a wireless access point, in accordance with a preferred embodiment of the present invention;

Fig. 4 is a block diagram that schematically illustrates communication links among multiple access points in a WLAN system, in accordance with a preferred embodiment of the present invention;

Fig. 5 is a block diagram that schematically illustrates communication and power links between an access point and a hub in a WLAN system, in accordance with a preferred embodiment of the present invention; and

Fig. 6 is a block diagram that schematically illustrates a message packet exchanged between access points in a WLAN system, in accordance with a preferred embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Fig. 1 is a block diagram that schematically illustrates a wireless LAN (WLAN) system 20, in accordance with a preferred embodiment of the present invention. System 20 comprises multiple access points 22, which are configured for data communication with mobile stations 24. The mobile stations typically comprise computing devices, such as desktop, portable or handheld devices, as shown in the figure. In the exemplary embodiments described hereinbelow, it is assumed that the access points and mobile stations communicate with one another in accordance with one of the standards in the IEEE 802.11 family and observe the 802.11 medium access control (MAC) layer conventions. Details of the 802.11 MAC layer are described in ANSI/IEEE Standard 801.11 (1999 Edition), and specifically in *Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications*, which is incorporated herein by reference. The principles of the present invention, however, are not limited to the 802.11 standards, and may likewise be applied to substantially any type of WLAN, including HiperLAN, Bluetooth and hiswan-based systems.

Access points 22 are typically connected to an Ethernet hub 26 by a wired LAN 28. The LAN serves as a distribution system (DS) for exchanging data between the access points and the hub. This arrangement enables mobile stations 24 to send and receive data through access points 22 to and from an external network 30, such as the Internet, via an access line 32 connected to hub 26. LAN 28 is typically capable of carrying data at high speeds – greater than the aggregate speed of wireless communications between the access points and mobile stations. Message latency on the LAN is high, however, generally on the order of milliseconds, due mainly to collision avoidance mechanisms that are inherent in the operation of Ethernet and other conventional LANs.

In addition to the conventional DS provide by LAN 28, access points 22 are also connected by a novel shared communication medium 34 to a MAC collaboration hub 36. Medium 34 may comprise substantially any suitable high-speed communication means, including wire, fiberoptics, or even free-space optical or radio communications (in an allowed frequency band that does not interfere with WLAN operation). For the sake of economy, medium 34 preferably comprises wires that run parallel to LAN 28. For example, medium 34 may comprise a twisted pair of wires that already exists in cabling of LAN 28, but which is not required for carrying LAN data. The function of MAC collaboration hub 36 is simply to connect medium 34 in such a way as to allow all access points 22 to broadcast and receive messages to and from all other access points. Therefore, unlike Ethernet hub 26, MAC collaboration hub 36 typically need not include a switch. Exemplary implementations of medium 34 and hub 36 are described hereinbelow with reference to Figs. 4 and 5. Although the hub-and-spokes topology shown in Figs. 1, 4 and 5 is generally the most convenient way to configure medium 34, alternative configurations will be apparent to those skilled in the art and are considered to be within the scope of the present invention.

Fig. 2 is a schematic illustration of simultaneous radio communications between mobile station 24 and multiple access points 22 in system 20, in accordance with a preferred embodiment of the present invention. It is assumed that the access points labeled AP1, AP2 and AP3 are all operating on the same band, over which mobile station 24 seeks to communicate. (Access points AP4 and AP5 are assumed to be operating in a different band, and thus do not participate directly in this communication process.) Radio waves 40, 42 and 44 reach mobile unit 24 from AP1, AP2 and AP3, respectively, with similar amplitudes. By the same token, radio messages transmitted by mobile unit 24 are received at about the same

time by AP1, AP2 and AP3. In WLAN systems known in the art, under these circumstances, mobile station 24 would receive downlink messages from two or more access points 22, which would probably result in inability of the mobile station to communicate with any of the access points. In preferred embodiments of the present invention, access points AP1, AP2 and AP3 communicate with one another over medium 34 in order to resolve this conflict, as described hereinbelow.

Fig. 3 is a flow chart that schematically illustrates a method for establishing communications between mobile station 24 and one of access points 22 in system 20, in accordance with a preferred embodiment of the present invention. Access points 22 (say AP1, AP2 and AP3) transmit beacon signals on their common frequency channel, at a beacon transmission step 50. In accordance with the 802.11 standard, the beacon signals transmitted by any given access point provide the time base with which the mobile station should synchronize its communications and indicate the BSS identification (BSSID) of the access point. The BSSID can be regarded as the MAC address of the access point. In 802.11 WLAN systems known in the art, each access point has its own unique BSSID. In system 20, however, access points AP1, AP2 and AP3 share the same BSSID, so that they appear logically to the mobile station to be a single, extended, distributed access point, which has multiple antennas at different locations. The time bases of AP1, AP2 and AP3 are mutually synchronized using medium 34, and the beacon signals transmitted by the access points are interlaced to avoid collision between them.

When mobile station 24 receives a beacon signal of sufficient strength, it extracts the BSSID and time base from the signal, at a beacon processing step 52. This step, as well as subsequent steps taken by the mobile station, is completely in accordance with the 802.11 standard. In other words, the present invention can be implemented in a manner that is transparent to and requires no modification of legacy mobile stations. Using the time base and BSSID it has acquired, mobile station 24 sends an uplink signal, in the form of an association request message that is addressed to the BSSID and indicates the MAC address of the mobile station, at an association request step 52.

Ordinarily, in a conventional WLAN, the access point to which the association request is addressed will answer immediately with an acknowledgment (ACK). If the mobile station does not receive the ACK within a given timeout period, typically 10 μs, it submits an

automatic repeat request (ARQ). Ultimately, the mobile station will treat the association request as having failed if it does not receive the required ACK. Therefore, to maintain 802.11 compatibility in system 20, one – and only one - of access points AP1, AP2 and AP3 must return an ACK to mobile station 24 within the 10 μs limit.

To determine which of the access points will respond to the association request message, access points AP1, AP2 and AP3 carry out an arbitration procedure using medium 34. For this purpose, all access points that received the association request message from mobile station 24 broadcast messages over medium 34, at a broadcast step 56, giving notice to the other access points that they have received an uplink message. Each broadcast message indicates the identity of the access point sending the message (i.e., a unique, internal identity, not the BSSID) and the MAC address of the mobile station in question. Preferably, to reduce the length of the broadcast message, the MAC address of the mobile station is hashed.

The access points send their messages over medium 34 in accordance with a predetermined protocol that makes it possible to distinguish messages sent simultaneously (or almost simultaneously) by different access points. For example, a time division multiple access (TDMA) protocol may be used, in which each access point has its own, assigned time slot. Alternatively, a code division multiple access (CDMA) protocol is used, as described below with reference to Fig. 6. Further alternatively, a frequency division multiplexing scheme may be used (or if medium 34 is implemented as a fiberoptic network, wavelength division multiplexing, as is known in the art).

The access points receive and process the broadcast messages sent over medium 34, at a processing step 58. Each access point is able to determine whether it was first to send its message, or whether another access point preceding it, by comparing the time of receipt of these broadcast messages to the time at which the access point sent its own broadcast message. (Access points operating on other frequency channels, as well as access points on the same frequency channel that did not receive an uplink signal from the mobile station identified in the broadcast message, may ignore the message.) Typically, the access point that was able to send its broadcast message first in response to an uplink message from a given mobile station is in the best position to continue communications with the mobile station, since this access point is generally the closest one to the mobile station. Therefore, all the access points independently choose this first access point to respond to mobile station 24. Alternatively,

other criteria, such as received signal power, may be applied in choosing the "winning" access point, as long as the criteria are applied uniformly by all the access points. Preferably, if a deadlock occurs (such as when two access points send their broadcast messages at the same instant), a predetermined formula is applied by all the access points to resolve the deadlock uniformly.

The winning access point sends the required ACK message to mobile station 24, at an acknowledgment step 60. As noted above, the ACK must be sent within a short time, typically 10 μs, and steps 56, 58 and 60 must all be completed within this time. Access points 22 are able to meet this time constraint by using medium 34 as a dedicated, shared medium for this purpose, and by implementing a fast arbitration protocol, based on short broadcast messages, as described above. After sending the ACK, the winning access point typically sends an association response message to mobile station 24, and then continues its downlink transmission to the mobile station as appropriate, at a downlink step 62.

The winning access point continues serving the mobile station until the mobile station sends another uplink message, at a new uplink step 64. The arbitration protocol described above is then repeated, starting from step 56. A different access point may be chosen to serve the mobile station in the next round, particularly if the mobile station has moved in the interim. Even if the mobile station has moved, there is no need to repeat the association protocol. As noted above, all the access points belong to the same BSS, as though they were a single extended access point. Therefore, the same association of the mobile station is therefore maintained even if the arbitration process among the access points chooses a different "winner" to respond to the next uplink packet from the mobile station.

Fig. 4 is a block diagram that schematically shows details of communications by access points 22 over medium 34, in accordance with a preferred embodiment of the present invention. Medium 34 in this embodiment comprise pairs of wires 68 connecting each of access points 22 to hub 36. Hub 36 comprises a splitter 70, which joins wires 68 in such a way that medium 34 functions as a shared medium, i.e., so that signals transmitted onto wires 68 by any of access points 22 are received by all the other access points on medium 34. In the simplified embodiment shown in Fig. 4, splitter 70 comprises a passive, inductive coupler, which couples together all the pairs of wires. Alternatively or additionally, splitter 70 may comprise one or more amplifiers or other active elements, as are known in the art.

Each access point 22 comprises a message processor 72 for communicating with the other access points over medium 34 and carrying out the MAC-level collaboration protocol described above. Message processor 72 typically comprises a transmit circuit 74 and a receive circuit 76, for transmitting and receiving broadcast messages over medium 34. Preferably, to meet the timing requirements of an 802.11 WLAN, as noted above, circuits 74 and 76 and medium 34 operate with a bandwidth of at least 30 MHz. Message processor 72 interacts with and controls a WLAN transceiver 78, in compliance with the collaboration protocol. Transceivers 78 communicate over the air with mobile stations 24 in accordance with the applicable WLAN standards.

Fig. 5 is a block diagram that shows further details of communications between one of access points 22 and hubs 26 and 36, in accordance with a preferred embodiment of the present invention. For the sake of simplicity, only a single access point is shown in this figure. Typically, multiple access points are connected in like manner, as shown in Fig. 4.

In the present embodiment, a multi-conductor cable 86 is used to connect access points 22 in LAN 28. Typically, cable 86 comprises CAT-5 cabling, as is common in Ethernet LANs. Two twisted pairs of wires 82 and 84 (the 1-2 and 3-6 pairs in a CAT-5 cable) are used for transmitting and receiving data packets over LAN 28, between Ethernet hub 26 and an Ethernet interface 80 in access point 22. These data packets may comprise data sent between mobile stations 24 and network 30, via the access points. A remaining twisted pair 88 (the 4-5 pair) is not generally used for LAN data communications. Therefore, pair 88 serves as medium 34, carrying MAC collaboration messages between message processor 72 and hub 36. This novel use of pair 88 eliminates the need for separate wiring of medium 34.

In some LANs (and particularly LANs that are used to connect wireless access points), pair 88 is also used to convey DC power to access points 22. A power distribution hub 90, associated with Ethernet hub 26, is connected by pair 88 to a power supply circuit 92 in access point 22. In accordance with the IEEE 802.3af draft standard, hub 90 supplies 48 VDC over pair 88. This voltage is stepped down and regulated by power supply circuit 92 in order to provide operating power to the communication circuits of access point 22. The DC level on the wires of pair 88, however, does not prevent pair 88 from serving as medium 34. Rather, message processor 72 comprises a high-frequency coupler 94, typically an inductive coupler, which separates the high-speed communication traffic on medium 34 from the DC power.

Fig. 6 is a block diagram that schematically illustrates a broadcast packet 100 sent over medium 34 by one of access points 22, in accordance with a preferred embodiment of the present invention. Packet 100 is used by the access points to convey broadcast notice messages when they receive uplink communications from one of mobile stations 24, as described above with reference to Fig. 3 (step 56). The present embodiment assumes that the access points communicate over medium 34 using a CDMA protocol. CDMA has the advantage, by comparison with TDMA, that it allows all the access points to broadcast simultaneously and does not require a master clock, delay compensation or an intelligent central unit.

Packet 100 comprises a preamble 102, which is typically made up of a synchronization word 104 and an access point identifier 106. As noted above, identifier 106 is a proprietary, internal identification code, which uniquely identifies the access point sending the packet. Message processor 72 in each of access points 22 preferably has a set of data masks, which correspond respectively to preambles 102 of all the other access points that are configured to transmit and receive on the same WLAN frequency channel. As the message processor receives data over medium 34, it compares the data against each of its masks in order to detect the beginning of a new packet and the identity of the access point that sent the packet. Walsh codes may be used advantageously for this purpose, as is known in the CDMA art.

Preamble 102 is followed by a broadcast message 108, which identifies the mobile station that sent the uplink message reported by packet 100. After message processor 72 has succeeded in decoding preamble with one of its data masks, it uses the same data mask to decode message 108. The message processor thus identifies both the mobile station that sent the uplink message and the access point that received it first, and in this way is able to decide which access point should respond to the uplink message, as described above. Optionally, message 108 may include other parameters, such as the power level of the received uplink message and/or an identification of the antenna on which the access point received the message. (For diversity purposes, access points generally have multiple antennas.) These additional parameters may be used, in addition to or instead of the time of receipt of packet 100, in arbitrating among the access points.

As noted above, although preferred embodiments are described herein with reference to particular types of wireless and wired LANs and particular communication standards, the principles of the present invention are similarly applicable to other types of LANs and

WLANs, which may operate in accordance with other standards. In addition, these principles may be applied in wireless personal area networks (PANs), as defined by IEEE Standard 802.15, including ultra-wide band (UWB) PANs. It will thus be appreciated that the preferred embodiments described above are cited by way of example, and that the present invention is not limited to what has been particularly shown and described hereinabove. Rather, the scope of the present invention includes both combinations and subcombinations of the various features described hereinabove, as well as variations and modifications thereof which would occur to persons skilled in the art upon reading the foregoing description and which are not disclosed in the prior art.

CLAIMS

1. A method for mobile communication, comprising:

arranging a plurality of access points in a wireless local area network (WLAN) to communicate on a common frequency channel with a mobile station;

receiving at one or more of the access points an uplink signal transmitted over the WLAN by the mobile station on the common frequency channel;

arbitrating among the access points receiving the uplink signal so as to select one of the access points to respond to the uplink signal; and

transmitting a response from the selected one of the access points to the mobile station.

2. A method according to claim 1, wherein the access points have respective service areas, and wherein arranging the plurality of the access points comprises arranging the access points so that the service areas substantially overlap.

3. A method according to claim 1, wherein arranging the plurality of the access points comprises arranging the access points to communicate with the mobile station substantially in accordance with IEEE Standard 802.11.

4. A method according to claim 3, wherein arbitrating among the access points comprises selecting the one of the access points to respond to the uplink signal within a time limit imposed by the IEEE Standard 802.11 for acknowledging the uplink signal.

5. A method according to any of the preceding claims, wherein arbitrating among the access points comprises sending messages over a shared communication medium linking the access points.

6. A method according to claim 5, wherein sending the messages comprises sending broadcast messages from the access points receiving the uplink signal to the plurality of the access points.

7. A method according to claim 6, wherein sending the broadcast messages comprises sending the messages over the shared communication medium from two or more of the access points simultaneously using a multiple access protocol.

8. A method according to claim 7, wherein the multiple access protocol comprises a code division multiple access (CDMA) protocol.

9. A method according to claim 5, wherein arbitrating among the access points comprises receiving and processing the messages at each of the plurality of the access points, so that each of the access points determines which one of the access points is to be selected to respond to the uplink signal.

10. A method according to claim 9, wherein processing the messages comprises selecting, responsive to the messages, the one of the access points that was first to receive the uplink signal.

11. A method according to claim 5, wherein sending the messages comprises indicating in the messages a strength of the uplink signal received by each of the access points.

12. A method according to claim 5, wherein arranging the plurality of the access points comprises linking the access points in a local area network (LAN) for conveying data to and from the mobile station, the LAN comprising a cable having multiple conductors, and wherein sending the messages comprises passing the messages over one or more of the conductors on the cable that are not used for conveying the data to and from the mobile station.

13. A system for mobile communication, comprising:

a communication medium; and

a plurality of access points interconnected by the medium and arranged in a wireless local area network (WLAN) to communicate on a common frequency channel with a mobile station, the access points being adapted, upon receiving at one or more of the access points an uplink signal transmitted over the WLAN by the mobile station on the common frequency channel, to arbitrate among the access points receiving the uplink signal by sending messages over the medium so as to select one of the access points to respond to the uplink signal, and to transmit a response from the selected one of the access points to the mobile station.

14. A system according to claim 13, wherein the access points have respective service areas and are arranged so that at least some of the service areas substantially overlap.

15. A system according to claim 13, wherein the access points are adapted to communicate with the mobile station substantially in accordance with IEEE Standard 802.11.

16. A system according to claim 15, wherein the access points are adapted to select the one of the access points to respond to the uplink signal within a time limit imposed by the IEEE Standard 802.11 for acknowledging the uplink signal.

17. A system according to any of claims 13-16, wherein the medium is configured as a shared communication medium.

18. A system according to claim 17, wherein the access points receiving the uplink signal are adapted to broadcast the messages over the medium to the plurality of the access points.

19. A system according to claim 18, wherein the access points are adapted so that two or more of the access points may broadcast the messages substantially simultaneously using a multiple access protocol.

20. A system according to claim 19, wherein the multiple access protocol comprises a code division multiple access (CDMA) protocol.

21. A system according to claim 17, wherein each of the plurality of the access points is adapted to receive and process the messages so as to determine which one of the access points is to be selected to respond to the uplink signal.

22. A system according to claim 21, wherein the access points are adapted to select, responsive to the messages, the one of the access points that was first to receive the uplink signal to respond to the uplink signal.

23. A system according to claim 17, wherein the access points are adapted to indicate in the messages a strength of the uplink signal received by each of the access points.

24. A system according to any of claims 13-16, and comprising a local area network (LAN), which comprises a cable having multiple conductors linking the access points, wherein the access points are adapted to convey data to and from the mobile station over the LAN, and wherein the communication medium comprises one or more of the conductors on the cable that are not used for conveying the data to and from the mobile station.

25. Access point apparatus for deployment in a wireless local area network (WLAN) as one of a plurality of access points for mobile communication, the apparatus comprising:

a radio transceiver, which is configured to communicate on a predetermined frequency channel with a mobile station; and

a message processor, which is adapted, when the transceiver receives an uplink signal transmitted over the WLAN by the mobile station on the predetermined frequency channel, to carry out an arbitration protocol together with others of the access points receiving the uplink

signal so as to select one of the access points to respond to the uplink signal, and to control the transceiver so that the transceiver returns a response to the mobile station subject to the arbitration protocol.

26. Apparatus according to claim 25, wherein the transceiver is adapted to communicate with the mobile station substantially in accordance with IEEE Standard 802.11.

27. Apparatus according to claim 26, wherein the message processor is adapted to carry out the arbitration protocol so as to select the one of the access points to respond to the uplink signal within a time limit imposed by the IEEE Standard 802.11 for acknowledging the uplink signal.

28. Apparatus according to any of claims 25-27, wherein the message processor is adapted to carry out the arbitration protocol by sending and receiving messages to and from the others of the access points over a shared communication medium linking the access points.

29. Apparatus according to claim 28, wherein the messages comprise broadcast messages, and wherein the message processor is adapted to send one of the broadcast messages when the transceiver receives the uplink signal.

30. Apparatus according to claim 29, wherein the message processor is adapted to send the messages over the shared communication medium using a multiple access protocol.

31. Apparatus according to claim 30, wherein the multiple access protocol comprises a code division multiple access (CDMA) protocol.

32. Apparatus according to claim 28, wherein the message processor is adapted to process the messages that it receives from the others of the access points so as to determine the one of the access points that was first to receive the uplink signal, and to select the one of the access points that was first to receive the uplink signal to respond to the uplink signal.

33. Apparatus according to claim 28, wherein the message processor is adapted to include in the messages that it send a strength of the uplink signal received by the transceiver.

FIG. 1

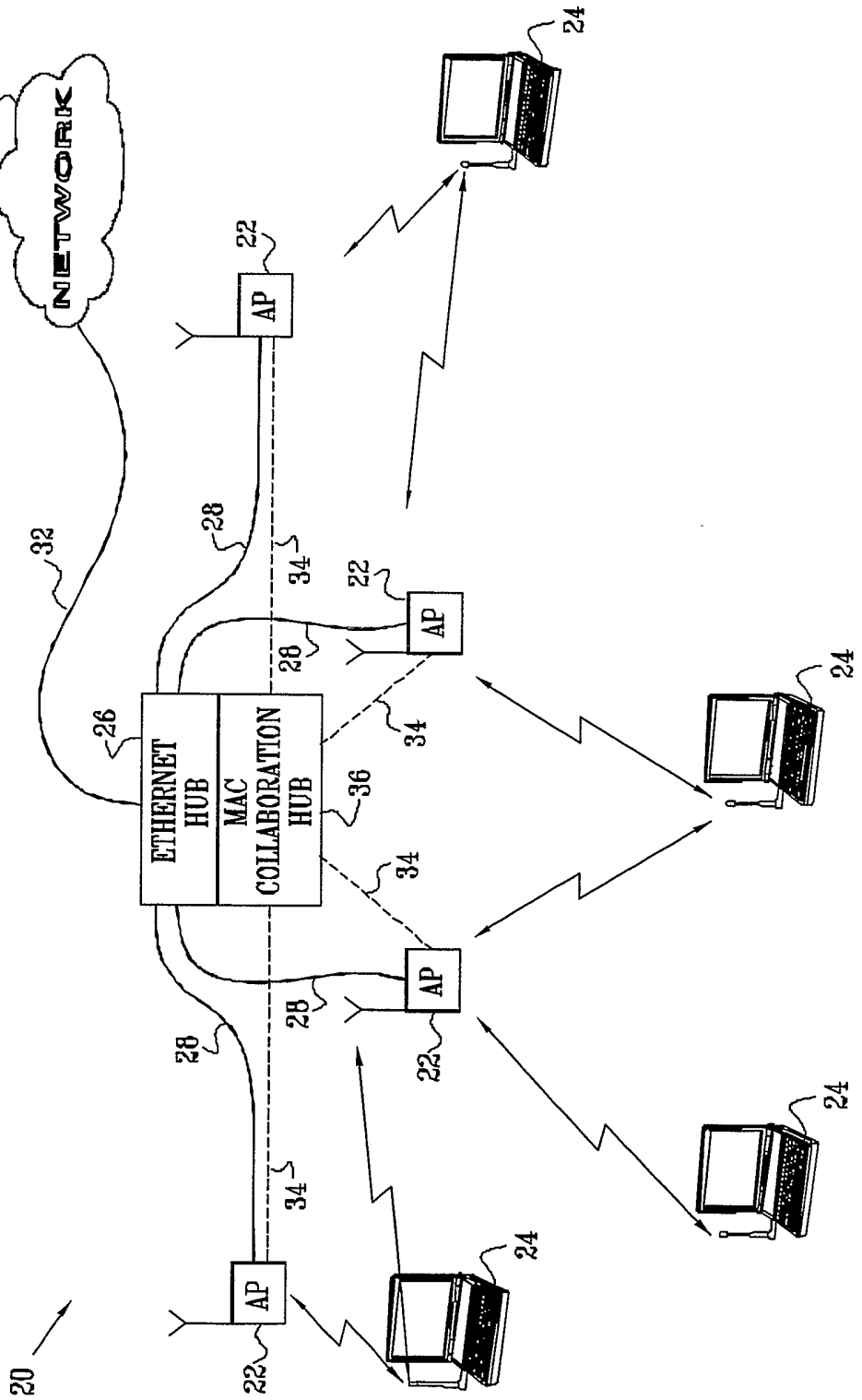

NETWORK
30
32
ETHERNET HUB
MAC COLLABORATION HUB
26
36
AP
22
28
34
24
20

FIG. 2

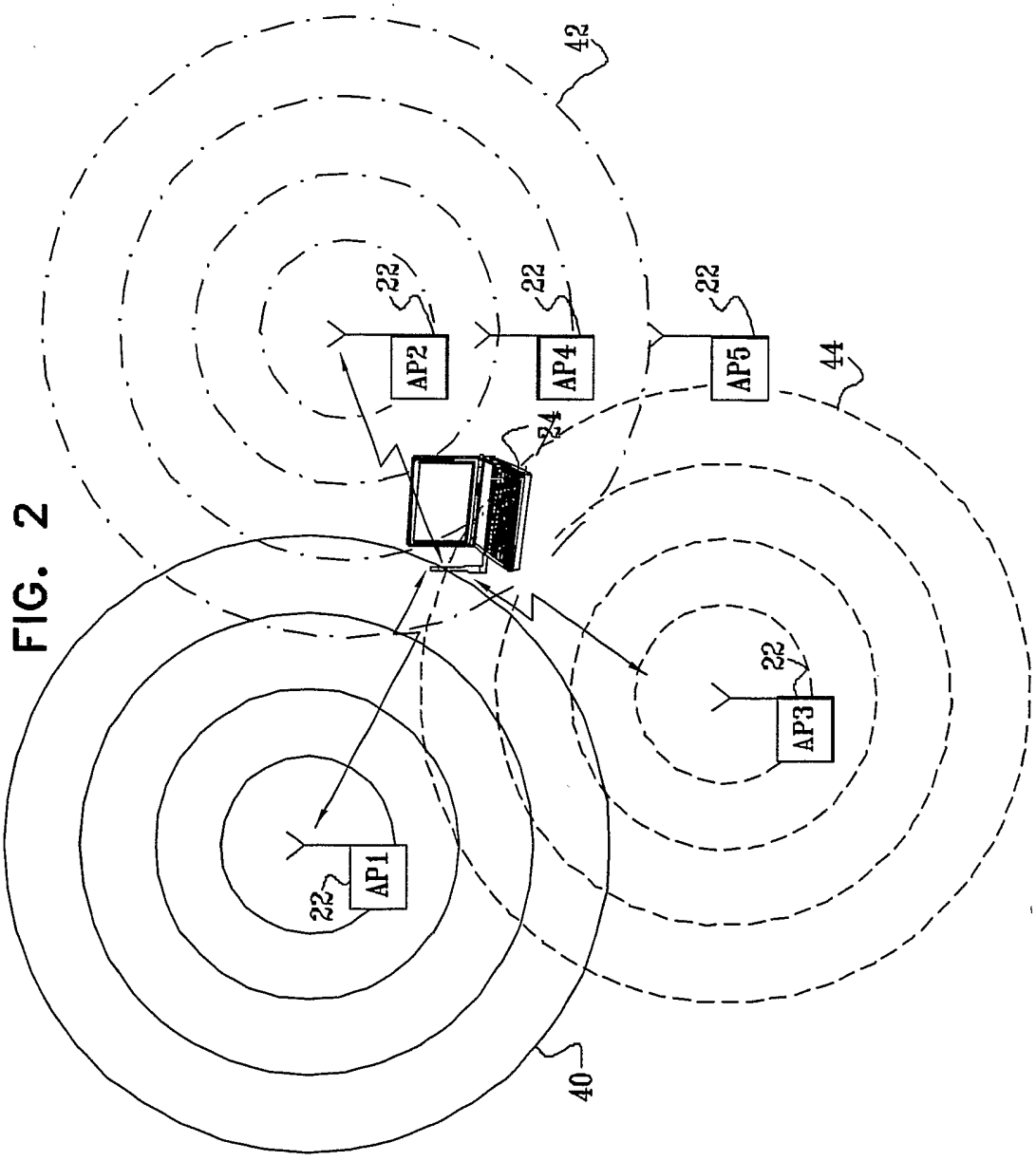


FIG. 3

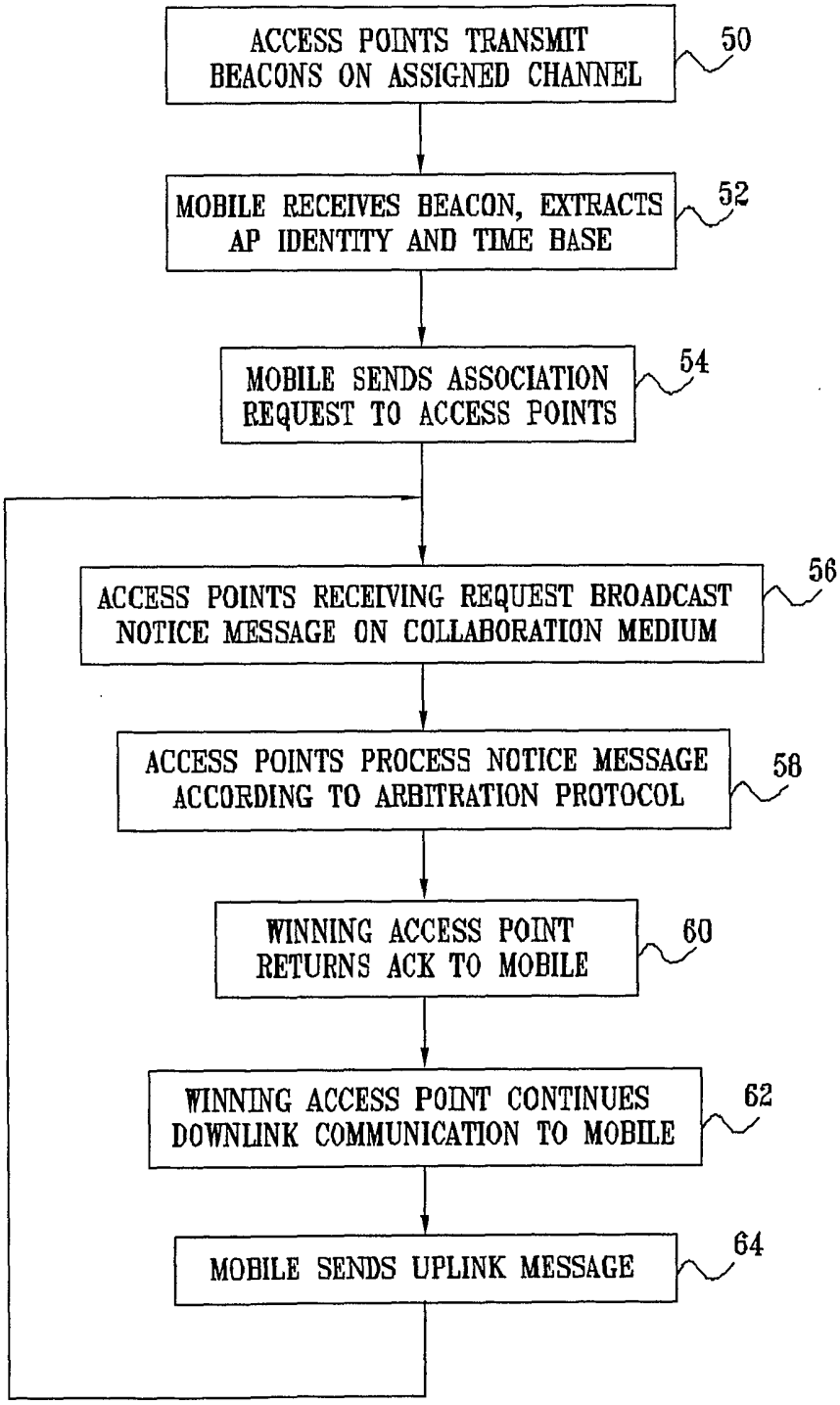
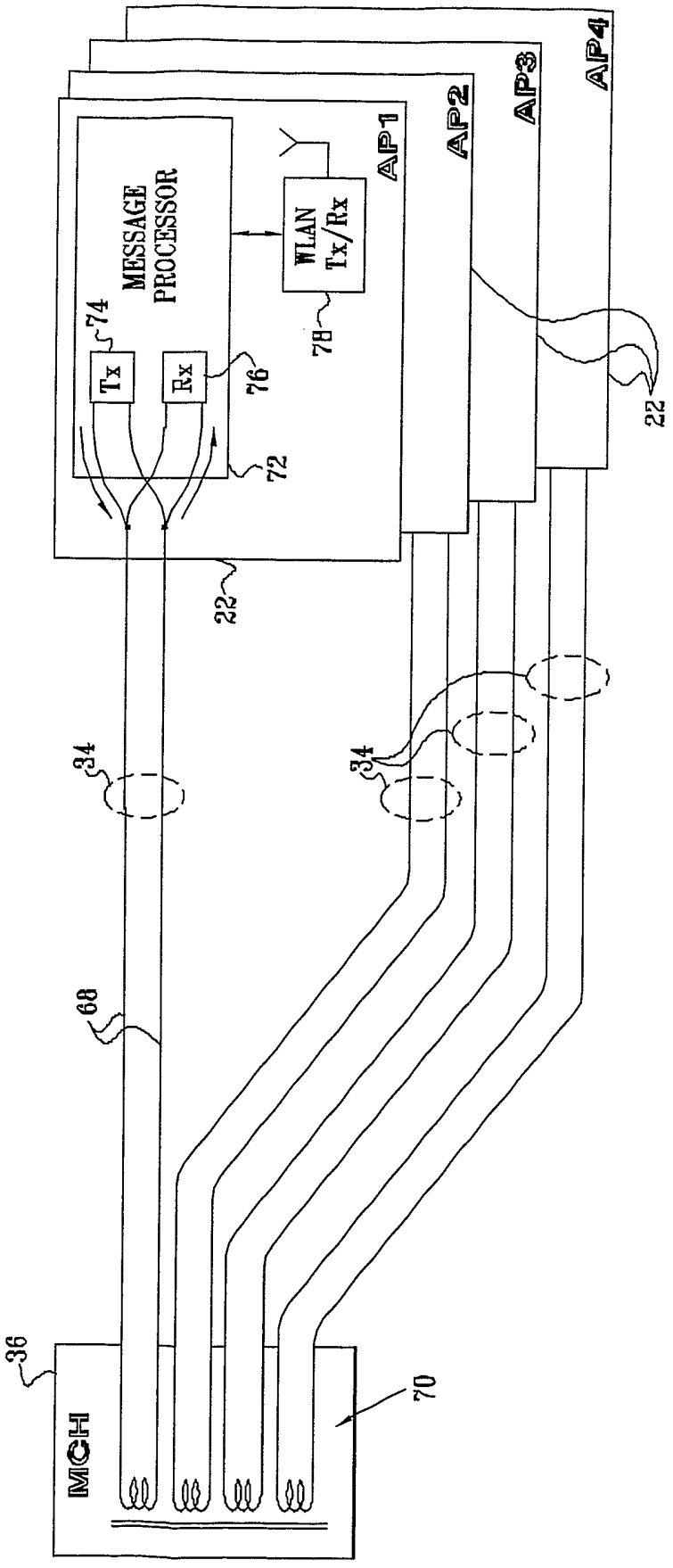

ACCESS POINTS TRANSMIT BEACONS ON ASSIGNED CHANNEL
50
MOBILE RECEIVES BEACON, EXTRACTS AP IDENTITY AND TIME BASE
52
MOBILE SENDS ASSOCIATION REQUEST TO ACCESS POINTS
54
ACCESS POINTS RECEIVING REQUEST BROADCAST NOTICE MESSAGE ON COLLABORATION MEDIUM
56
ACCESS POINTS PROCESS NOTICE MESSAGE ACCORDING TO ARBITRATION PROTOCOL
58
WINNING ACCESS POINT RETURNS ACK TO MOBILE
60
WINNING ACCESS POINT CONTINUES DOWNLINK COMMUNICATION TO MOBILE
62
MOBILE SENDS UPLINK MESSAGE
64

FIG. 4


AP4
AP3
AP2
AP1
MESSAGE PROCESSOR
WLAN Tx/Rx
Tx
Rx
74
76
78
72
22
34
68
36
MCH
70

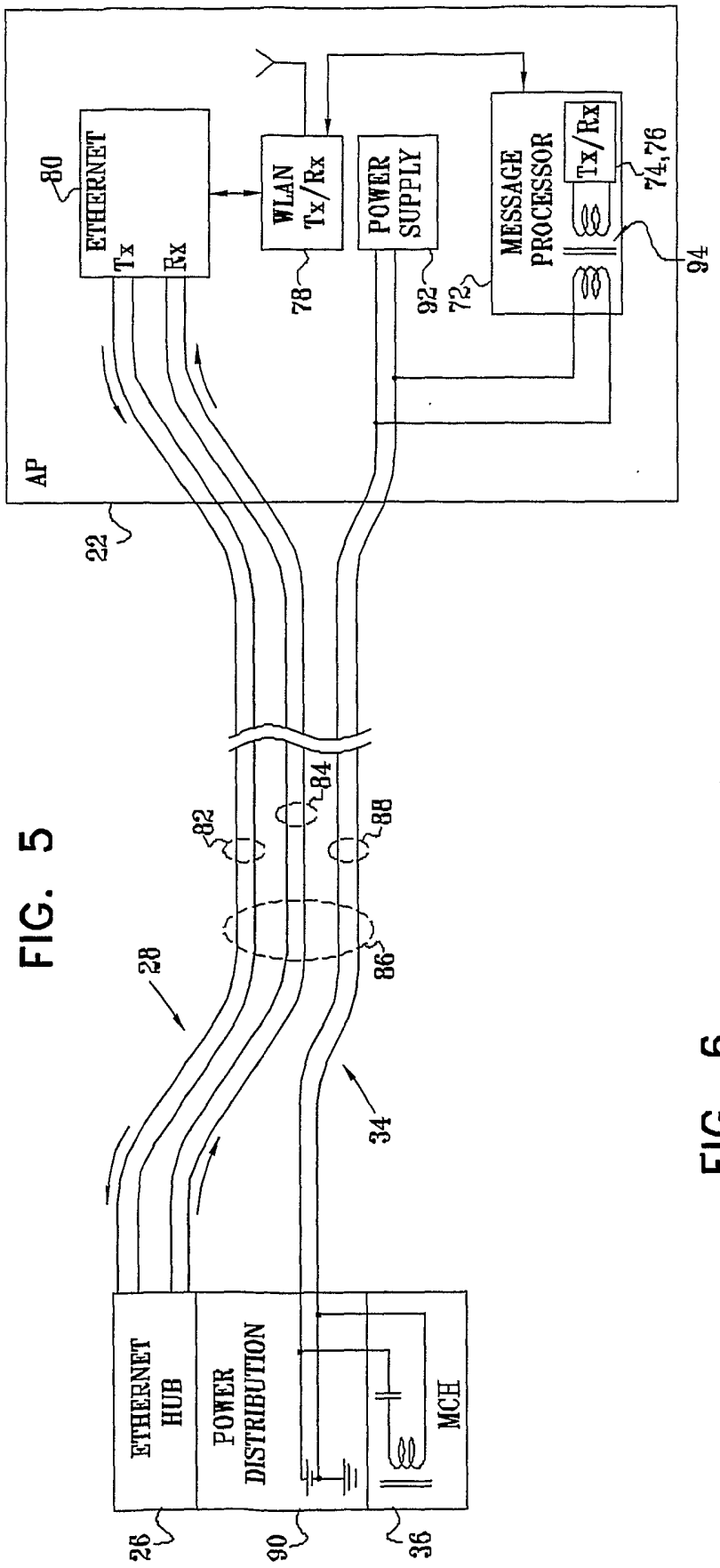

AP
ETHERNET
Tx
Rx
80
WLAN
Tx/Rx
78
POWER
SUPPLY
92
MESSAGE
PROCESSOR
72
Tx/Rx
74,76
94
22
82
84
88
86
28
34
ETHERNET
HUB
POWER
DISTRIBUTION
MCH
26
90
36

FIG. 5

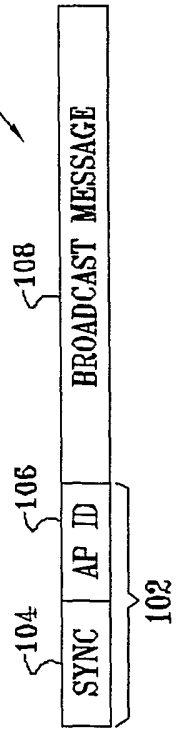

100
108
BROADCAST MESSAGE
106
AP ID
104
SYNC
102

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IL03/00617

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : H04B 7/15; H04Q 7/20

US CL : 455/11.1, 445, 423, 67.11

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)

U.S. : 455/11.1, 445, 423, 67.11

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)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y,P	US 2002/0197984 A1 (MONIN et al) 26 December 2002, see entire document	1-33
X,P	US 2003/0181221 A1 (NGUYEN) 25 September 2003, see entire document	1-4, 13-17 and 25-28
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Y,P		5-12, 18-24 and 29-3328
A,P	US 2003/0012174 A1 (BENDER et al) 16 January 2003, see entire document	1-33

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

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"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

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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
19 October 2003 (19.10.2003)	02 DEC 2003
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. (703)305-3230	Authorized officer Edan Orgad Telephone No. 703-305-4223

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