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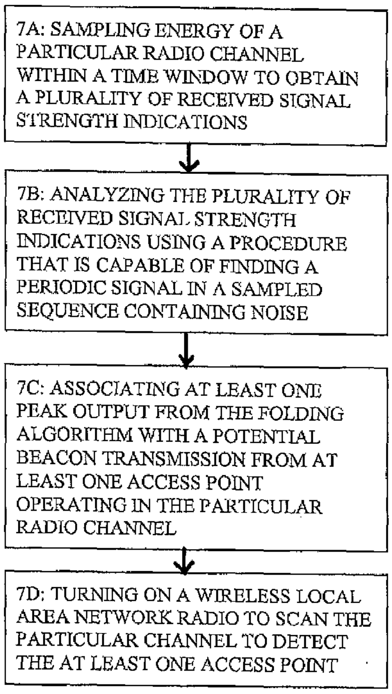

FIGURE 7

(57) Abstract: A method includes sampling energy of a particular radio channel within a time window to obtain a plurality of received signal strength indications; analyzing the plurality of received signal strength indications using a procedure that is capable of finding a periodic signal in a sampled sequence containing noise, such as a folding algorithm; associating at least one peak that is output from the folding algorithm with a potential beacon transmission from at least one access point operating in the particular radio channel; and turning on a wireless local area network radio to scan the particular channel to detect the at least one access point.

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USE OF LOW POWER RADIO TO DETECT PRESENCE OF ACCESS POINT

TECHNICAL FIELD:

The exemplary and non-limiting embodiments of this invention relate generally to wireless communication systems, methods, devices and computer programs and, more specifically, relate to wireless local area networks, access points, beacon transmissions and low power radio.

BACKGROUND:

This section is intended to provide a background or context to the invention that is recited in the claims. The description herein may include concepts that could be pursued, but are not necessarily ones that have been previously conceived, implemented or described. Therefore, unless otherwise indicated herein, what is described in this section is not prior art to the description and claims in this application and is not admitted to be prior art by inclusion in this section.

The following abbreviations that may be found in the specification and/or the drawing figures are defined as follows:

AP	access point
BER	bit error rate
BT	Bluetooth
BT-LE	Bluetooth low energy
CSMA-CA	collision sense multiple access-collision avoidance
MAC	medium access control
OFDM	orthogonal frequency division multiplex
RSSI	received signal strength indicator
SNR	signal to noise ratio
SSID	service set identifier
UTRAN	universal terrestrial radio access network
WiFi	device compatible with IEEE 802.11 technology
WLAN	wireless local area network

Modern mobile communication devices can be equipped with multiple network interfaces. These network interfaces can include one or more cellular interfaces (e.g., GSM, UTRAN, and evolved UTRAN) as well as short range radio interfaces such as WLAN, Bluetooth and BT-LE.

Among the available data communication technologies on current mobile communication devices, which may be referred to as "smartphones", are technologies to access the Internet. IEEE 802.11 is one such technology. IEEE 802.11 has certain features that make it a desirable choice for data communication. First, it is a relatively short-range radio technology, therefore it offers high data rates and consumes less energy per byte than longer-range radio technologies. Further, using freely available organizational or home WiFi networks is convenient and typically less expensive that using cellular and other longer range radio technologies.

In order to locate WLAN connectivity opportunities a mobile communication device needs to periodically scan its environment. Once a usable AP is discovered the WLAN radio interface can associate with it and begin communication. If a mobile communication device has pending data to send or receive, the WLAN interface should be active and scanning even when it is not associated with any AP(s). However, according to the WiFi/IEEE 802.11 protocol, each mobile device must execute in order a scanning, an authentication and an association operation to access an available AP. As a result, the WLAN interface (a WiFi module) can consume a considerable amount of energy (e.g., about 1W) while scanning, even when the mobile device is idle. As may be appreciated the need to scan the environment regularly to discover available AP(s) can quickly discharge the battery of the mobile device.

Various approaches for dealing with this issue have been proposed. In one general class of approaches there is an attempt to improve the scheduling strategy of waking up the IEEE 802.11 radio (i.e., exiting a low power state to a higher power state). One approach described by M.H. Falaki, WLAN Interface Management on Mobile Devices, Master's thesis, University of Waterloo, Canada, 2008, attempts to learn the distribution of APs based on historical connection information. The IEEE 802.11 radio is then turned on when the device is estimated to be in connection range of an AP. Another approach, described by A. J. Nicholson and B. D. Noble, BreadCrumbs: Forecasting mobile connectivity, In Proceedings of The Fourteenth Annual International Conference on Mobile Computing and Networking (Mobicom =08), Sep 2008 utilizes GPS and a location database of a cellular tower to record the location of available APs and power on the WiFi interface when moving into a nearby area. Another approach, described by Ananthanarayanan G, Stoica I., Blue-Fi: enhancing Wi-Fi performance using Bluetooth signals, In Proceedings of the 7th international conference on Mobile systems, applications, and services. Krakow, Poland: ACM; 2009, pgs.:249-262, predicts an available AP by making use of the cell tower information and Bluetooth contact information. The intuition is that users always meet repeatedly in range of the same cell tower set using the Bluetooth devices such as a BT mouse, phones and printers.

Another general class of approaches seeks to use collaboration of multiple radios. For example, Y. Agarwal, R. Chandra, A. Wolman, P. Bahl, and R. Gupta, Wireless Wakeups Revisited: Energy Management for VoIP over WiFi Smartphones, In Proceedings of the Fifth International Conference on Mobile Systems, Applications, and Services (MobiSys >07), Jun 2007; E. Shih, P. Bahl, and M. J. Sinclair, Wake on wireless: An event driven energy saving strategy for battery operated devices, In Proceedings of the Eighth Annual International Conference on Mobile

Computing and Networking (MobiCom =02), 2002; and Y. Agarwal, C. Schurgers, and R. Gupta, Dynamic Power Management Using On Demand Paging for Networked Embedded Systems, In Proceedings of the 2005 Conference on Asia South Pacific Design Automation (ASP-DAC =05), Jan 2005, propose the use of separate low power radios to serve as a separate out-of-band wake-up channel for a higher power WiFi radio. However, these three methods require either additions to the network infrastructure or modifications to intermediate proxies. In addition, T. Pering, Y. Agarwal, R. Gupta, and R. Want, Coolspots: Reducing the power consumption of wireless mobile devices with multiple radio interfaces. In Proceedings of the Fourth International Conference on Mobile Systems, Applications, and Services (MobiSys =06), Jun 2006; and A. Rahmati and L. Zhong, Context-for-Wireless: Context-Sensitive Energy-Efficient Wireless Data Transfer, In Proceedings of The Fifth International Conference on Mobile Systems, Applications, and Services (MobiSys =07), Jun 2007 aim to reduce energy consumption of mobile devices by dynamically choosing between multiple available wireless interfaces for data transfer based on various factors. N. Mishra, K. Chebrolu, B. Raman, and A. Pathak, Wake-on-WLAN, in WWW=06, May 2006, describe a research project based on a scenario of rural connectivity. In Wake-on-WLAN, wake-up signals propagate down a mesh network to establish network connectivity on-demand, building up the network path one hop at a time until end-to-end connectivity is achieved. Mishra N, Golcha D, Bhadauria A, Raman B, Chebrolu K., S-WOW: Signature based Wake-on-WLAN, in Communication Systems Software and Middleware, 2007, COMSWARE 2007, 2nd International Conference on.; 2007:1-8, describe an improvement to the WoW approach to make it run in an environment with noise. In addition, Chebrolu K. and Dhekne A., Esense: Communication through Energy Sensing, In Proceedings of the 15th Annual International Conference on Mobile Computing and Networking, Beijing, China: ACM 2009:85-96 describe an exchange control information between devices with different physical layer communication technologies, and use the detection of channel energy which is predefined as a set of energy patterns.

Reference can also be made to the following patent documents: Techniques to use location information to reduce scanning in wireless networks, US 2008/0117862 A1; Method and apparatus for indicating the presence of a wireless local area network by detecting signature sequences, US 6754194; Method of scanning for beacon transmissions in a WLAN, US 7224970; Method and system for wireless LAN network detection US 2007/0140157 A1; Wireless local access network system detection and selection, US 7146130; and System And Method For Integrated WiFi/WiMax Neighbor AP Discovery and AP Advertisement, US 2007/0140163 A1.

Prior to this invention there was no satisfactory energy-efficient solution to the problems that arise when operating a battery-powered device to detect and associate with an access point in a wireless local area network, such as one defined by IEEE 802.11.

SUMMARY

The foregoing and other problems are overcome, and other advantages are realized, by the use of the exemplary embodiments of this invention.

In a first aspect thereof the exemplary embodiments of this invention provide a method that comprises sampling energy of a particular radio channel within a time window to obtain a plurality of received signal strength indications; analyzing the plurality of received signal strength indications using a procedure that is capable of finding a periodic signal in a sampled sequence containing noise; associating at least one peak output from the procedure with a potential beacon transmission from at least one access point operating in the particular radio channel; and turning on a wireless local area network radio to scan the particular channel to detect the at least one access point.

In a further aspect thereof the exemplary embodiments of this invention provide an apparatus that comprises a processor and a memory including computer program code. The memory and computer program code are configured to, with the processor, cause the apparatus at least to perform, sampling energy of a particular radio channel within a time window to obtain a plurality of received signal strength indications; analyzing the plurality of received signal strength indications using a procedure that is capable of finding a periodic signal in a sampled sequence containing noise; associating at least one peak output from the procedure with a potential beacon transmission from at least one access point operating in the particular radio channel; and turning on a wireless local area network radio to scan the particular channel to detect the at least one access point.

BRIEF DESCRIPTION OF THE DRAWINGS

In the attached Drawing Figures:

Figure 1 is a system/device level block diagram that shows a mobile communication device that is constructed and operated in accordance with the exemplary embodiments of this invention.

Figure 2 shows typical beacon transmissions from an access point in an IEEE 802.11 network.

Figure 3 shows a spectrum of a particular IEEE 802.15.4 compatible device and a spectrum of IEEE 802.11.

Figure 4 shows an exemplary sample sequence for the typical beacon transmissions depicted in Figure 2.

Figure 5 illustrates a typical example of an output obtained through the use of a folding algorithm

Figure 6 shows a typical distribution of restricted and open networking channels in IEEE 802.11.

Figure 7 is a logic flow diagram that illustrates the operation of a method, and a result of execution of computer program instructions embodied on a computer readable memory, in accordance with the exemplary embodiments of this invention.

DETAILED DESCRIPTION

Figure 1 illustrates a simplified block diagram of various electronic devices and apparatus that are suitable for use in practicing the exemplary embodiments of this invention. In Figure 1 there is shown an apparatus that may be referred to as a mobile communication device (MCD) 10, as well as a plurality of APs 30 (AP_1, AP_2,..., AP_n). The APs 30 will, in general, provide the MCD 10 with bidirectional radio connectivity to one or more data communication networks, such as intranets, extranets, local area networks and wide area networks, including the Internet.

The MCD 10 includes a controller, such as at least one computer or a data processor (DP) 12A, a computer-readable memory medium embodied as at least one memory (MEM) 14 that stores a program of computer instructions (PROG) 14A and, optionally, at least one suitable RF (e.g., cellular) transceiver 16 for bidirectional wireless communications with a cellular access node, such as a base station or Node B (not shown), via one or more antennas. The cellular transceiver 16 may be operable with any type of cellular air interface, including one or more of time divisional multiple access, code division multiple access, wideband code division multiple access, and orthogonal frequency division multiple access, as non-limiting embodiments. Note that in some embodiments, such as in non-smartphone embodiments, the MCD 10 may not include the cellular transceiver 16.

The MCD 10 is also assumed to include a WLAN module 18 that has a wireless transceiver and related components suitable for conducting wireless communications with the APs 30. The WLAN module 18 may be compatible with IEEE 802.11-type of (WiFi) operation (e.g., IEEE 802.11b or 802.11g).

In accordance with the exemplary embodiments of this invention the MCD 10 also includes a low power radio module that includes at least a radio receiver. As such, for the purposes of describing this invention the MCD 10 also includes a low power receiver module 20. As a non-limiting example the low power receiver module 20 may be one compatible with IEEE 802.15 TG4. This particular type of interface features data rates of 250 kbps, 40 kbps, and 20 kbps; two addressing modes: 16-bit short and 64-bit IEEE addressing; support for critical latency devices, such as joysticks; CSMA-CA channel access; automatic network establishment by a coordinator; a fully handshake protocol for transfer reliability; power management to ensure low power consumption; and operability over 16 channels in the 2.4GHz ISM band, 10 channels in the 915MHz band and one channel in the 868MHz band. IEEE 802.15 TG4 is designed to be a lower power version of IEEE 802.11/Wi-Fi, and may be referred to as IEEE 802.15.4/ZigBee, and in particular, for example, ZigBee RF4CE (www. zigbee.org/rf4ce). ZIGBEE7 is a registered trademark of Zigbee Alliance Corporation. The ZigBee RF4CE operates in only a small subset of the channels specified for IEEE 802.15.4, specifically channels 15, 20 and 25.

As another non-limiting example the low power receiver module 20 may be one compatible with Bluetooth Low Energy (LE), which also operates in the 2.4GHz band. In general, Bluetooth LE has reduced operating current requirements as compared to conventional Bluetooth. BLUETOOTH7 is a registered trademark of Bluetooth Sig., Inc.

As employed herein the low power receiver module 20 is assumed to consume less energy during a period of operation than would be consumed by the WLAN module 18. For example, if the WLAN module 18 is assumed to consume 1 Watt, then the low power receiver module 20 may be assumed to consume some fraction of 1 Watt (e.g., 0.1 W). If one also assumes that the MCD 10 is powered by a battery, or some other consumable power source, then operation of the low power receiver module 20 will draw less current per unit time from the power source than will operation of the WLAN module 18.

The PROG 14A is assumed to include program instructions that, when executed by the associated DP 12, enable the MCD 10 to operate in accordance with the exemplary embodiments of this invention, as will be discussed below in greater detail. In general, the exemplary embodiments of this invention may be implemented at least in part by computer software executable by the DP 12, or by hardware, or by a combination of software and hardware (and firmware). The computer readable memory 14 may be of any type suitable to the local technical environment and may be implemented using any suitable data storage technology, such as semiconductor based memory devices, flash memory, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory. The data processor 12 may be of any type suitable to the local technical environment, and may include one or more of general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs) and processors based on multi-core processor architectures, as non-limiting examples.

The various embodiments of the MCD 10 can include, but are not limited to, cellular telephones, personal digital assistants (PDAs) having wireless communication capabilities, portable computers having wireless communication capabilities, image capture devices such as digital cameras having wireless communication capabilities, gaming devices having wireless communication capabilities, music storage and playback appliances having wireless communication capabilities, Internet appliances permitting wireless Internet access and browsing, as well as portable units or terminals that incorporate combinations of such functions.

In the ensuing description of the exemplary embodiments of this invention the low power receiver module 20 will be described in the context of IEEE 802.15.4, and more specifically, for convenience only, in the context of ZigBee. However, the exemplary embodiments may be realized using any suitable low power receiver module 20, such as one based on Bluetooth LE, or a low power receiver interface designed specifically for use with the exemplary embodiments of this invention.

In accordance with the exemplary embodiments the low power receiver module 20 is used to periodically sample the channel energy within a time window and obtain the RSSI of the channel. The sampled channel energy is then analyzed, and the sequence of the sampled received signal strength indications is evaluated to determine whether there is a specific pattern present. The specific pattern is one that would be expected if at least one IEEE 802.11 standard compatible AP 30 is operating within the reception range of the low power interface 20, and is periodically transmitting beacon frames. If the pattern is found to exist then it can be inferred that there is at least one of the APs 30 operating in a specific channel in a usable communication range. The WiFi interface (WLAN module 18) is then powered on to scan the channel in order to find and connect to the detected AP 30.

More specifically, and discussing first the available characteristics in the IEEE 802.11 standard specifications, each AP 30 is required to periodically broadcast a beacon management frame. The default beacon transmission time period is 100ms. Although the AP 30 may be configured differently is some cases, the period would still be set to 100ms most of the time. The length of a beacon frame is about 100 bytes. The duration of a beacon frame on the air is 192+100*8/1=992 microseconds (for IEEE 802.11b) or 192+100*8/6=315 microseconds (for IEEE 802.11g). Because of the CSMA-CA mechanism used in IEEE 802.11 the time at which a beacon frame occurs in the channel can deviate by a small amount when the network is busy. Typical beacon transmissions in a network are illustrated in Figure 2. Note that the actual beacon transmission times can deviate from the default beacon transmission interval as a function of network loading.

Discussed now is the sampling the channel energy of IEEE 802.11 traffic through the low power receiver interface 20. For the sake of clarity one may assume IEEE 802.11b as an example. IEEE 802.11b and Zigbee operate in the same ISM spectrum from 2.4 to 2.483 GHz. Thus, the Zigbee receiver that forms part of the low power receiver module 20 can receive the IEEE 802.11b signal in the same channel. One particular type of Zigbee implementation may exhibit a maximum RSSI sample rate of about 6000 Hz or higher (e.g., a CC2420 Zigbee chip can reach a 30Khz sample rate. Assuming the non-limiting case of a 6000 Hz sampling rate, this implies that a sample is taken about every 165 microseconds. Referring to Figure 4, one may use "1" to denote an occurrence of high energy (sampled RSSI) in the channel and a "0" to denote an absence of high energy (e.g., background noise). In this case (e.g., assuming a beacon frame time of about 990 microseconds and a sampling period of about 165 microseconds) each beacon transmission (denoted as "B") is represented as six or seven consecutive "1" indications.

Having thus accumulated some amount of RSSI sampling data, a next step detects the beacon signal pattern in the sampled sequence of "1" and "0" indications. Assume without imposing a limitation that a sample window has a duration of two seconds. In this case the sequence length is 2*6000=12000 sample indications, and 20 IEEE 802.11 beacon packets or frames should be included in the sample sequence if no beacon packet is missed or destroyed due to collision.

It should be noted that RSSI absolute values can also be collected for use in evaluating the quality of a particular channel relative to other channels. The absolute RSSI sequence can be converted to the binary notation according to some specified noise RSSI threshold.

The exemplary embodiments of this invention can use a folding algorithm (see D.H. Staelin, Fast Folding Algorithm for Detection of Periodic Pulse Trains, Proceedings of the IEEE, Vol. 57, No. 4, April, 1969, pp.724-725, 1969) to detect the periodic beacon packet. The folding algorithm is an effective method to detect a hidden periodic signal in a time series. Briefly, the folding algorithm divides the time series into a set of smaller sequences each having the same length, and then adds the set of smaller sequences together. If the length of the divided sequence is equal to the period of the periodic signal, the periodic signal will be added multiple times at the same point and thus will constructively add and become evident, while other (non-periodic) signals will appear as white noise because they are distributed in what may be considered to be a random or substantially random fashion. A typical example of the output of the folding algorithm is shown in Figure 5. The location of the peak in the average signal power indicates where the period occurs in the series and, thus, indicates the presence of an AP 30 beacon transmission. It is pointed out that multiple peaks can occur when there are multiple APs operating in a channel, and that there can (typically) be differences in the values of the average signal powers of the multiple peaks depending on, for example, the distance of each corresponding AP 30 from the MCD 10.

It is also pointed out that the exemplary embodiments of this invention are not limited for use with only the folding algorithm, and that any signal processing algorithm or procedure that is capable of finding a periodic signal in a sampled sequence (series of points) containing noise can be used. Non-limiting examples include the use of a Fourier transform-based searching procedure and a simple string pattern matching algorithm.

For the purposes of describing the exemplary embodiments of this invention the program 14A stored in the memory 14 can be assumed to include program instructions that, when executed by the data processor 12, result in the MCD 10 operating to sample energy of a particular radio channel within a time window to obtain a plurality of received signal strength indications; to analyze the plurality of received signal strength indications using the folding algorithm; to associate at least one peak output from the folding algorithm with a potential beacon transmission from an access point operating in the particular radio channel; and to turn on the wireless local area network radio (WLAN module 18) to scan the particular channel to detect the access point.

In addition, the exemplary embodiments of this invention can be used identify the data rate of the AP 30 by examining the sequence length of a beacon frame. This additional information can be used to optimize the selection of an AP 30.

More specifically, the use of the exemplary embodiments of this invention enables a determination of the AP 30 data rate by analyzing the number of sampling points corresponding to a beacon packet. According to the IEEE 802.11 protocol, each beacon MAC management packet is about 100 bytes long. A complete beacon frame occurring in the air interface has three parts: preamble, header and MAC frame. The three parts are modulated and sent to the antenna with different modulation standards as specified in IEEE 802.11b and IEEE 802.11g. The beacon frame is always transmitted at the supported lowest data rate (1 Mbps (million bits per second) for IEEE 802.11b and 6 Mbps for IEEE 802.11g (OFDM)). Thus, the exemplary embodiments of this invention can be used to determine the maximum data rate of an AP 30 by counting the corresponding number of sampling points (RSSIs) corresponding to a single beacon frame.

In operation, the low power receiver module 20 wakes up periodically to sample some channel or channels in IEEE 802.11. These channels may be referred to as popular channels that are predetermined in some manner, such as channels 1, 6 and 11 shown in Figures 3 and 6. Note that Figure 3 shows the non-limiting case of the Zigbee implementation using at least IEEE 802.15.4 channels 15, 20 and 25. The low power receiver module 20 operates in each channel and samples the channel energy for several seconds. It should be noted that it is not necessary for the low power receiver 20 to operate in all 15 channels since it can detect the energy of signals transmitted in nearby 1 or 2 channels. For example, a Zigbee or similar receiver operating in channels 17 and 18 can detect the energy of IEEE 802.11 channel 6. In general, it is not necessary to accurately align the IEEE 802.11 channels with the IEEE 802.15.4 channels. Also, the sample time window of around 800ms is sufficient to achieve the high probability of identifying an AP 30. Through the use of the folding algorithm (or some other suitable algorithm or procedure that is capable of finding a periodic signal in a sampled sequence containing noise) the presence of at least one periodic beacon frame from at least one AP 30 may be detected in at least one channel (if any APs 30 are present at all). After detecting the presence of at least one periodic beacon packet in the sample series the mobile communication device 10 is enabled to select an AP 30 having the best quality according to the RSSI, and possibly also the data rate. The WLAN (WiFi) module 18 is then brought out of the low power mode and instructed to scan a particular IEEE 802.11 channel. After the WLAN module 18 discovers the AP 30 in the scanned channel it can further associate with the discovered AP 30 and operate in a normal fashion.

As can be clearly seen in the example of Figure 3, the wireless local area network radio (WLAN module 18) and the radio receiver used for sampling (low power receiver 20) operate in the same radio spectrum but with different channelizations.

It can be noted that the WLAN module 18, which characteristically consumes more energy than the low power receiver module 20, is not activated until a candidate AP 30 is discovered, thereby reducing the power consumption of the MCD 10 and lengthening the time between needed battery recharge operations.

For example, assume that the average power of the WiFi interface (WLAN module 18) is about 1W (the actual power consumption may typically be higher when scanning). Assume also that the average power of the low power receiver module 20 is about 60-100mW. In a typical application the WLAN scanning may be performed with a period of 60 seconds. The time to power on the WLAN module 18, plus the scanning duration, may be assumed to be about 4 seconds. Also assume then that the low power interface 20 operates with a period of 60 seconds and the working duration is about 8 seconds (as it takes some time to sample multiple channels). As was stated above, the low power receiver module 20 can detect the energy of neighbor channels. Thus, the low power receiver module 20 need at most detect respectively 5 channels to cover all 15 channels. It takes 800 ms to sample the RSSI and thus the total time cost is about 5*800ms=4seconds. Here, an 8 second window is used simply to compare the performance. If one begins scanning for an AP 30 at time 0, and until an AP is detected at time T, the power consumption of WLAN scanning would be (T/60)*4*1, while the power consumption using the exemplary embodiments of this invention would be (T/60)*8*0.1, which is significantly less. Also, in a realistic situation T may be large considering movement of the MCD 10 and possibly a sparse AP 30 deployment in certain environments. Thus, as the value of T increases the power savings increase as well.

It can be noted that the low power receiver module 20 need only sample the channel energy (and develop the received signal strength indications). The actual communication range of the low power receiver module 20 is not a factor. As a result the technique provided by the exemplary embodiments is operable as long as there is energy in the channel. In those cases where the BER is high and/or the SNR is low, or the AP 30 is located far from the MCD 10, the use of the exemplary embodiments can successfully detect the AP 30, as it is only necessary to sample the channel energy. In contrast, conventional WLAN scanning can fail due to low signal strength or SNR, as the received signal cannot be properly demodulated.

Should the use of these exemplary embodiments require some additional time to collect the channel energy information, the additional time needed is compensated for in at least two aspects: 1) as described above, as compared to a conventional WiFi scanning procedure the AP 30 can be detected at a greater distance, implying the AP 30 can be detected earlier than it would be during conventional WiFi scanning (which is beneficial for at least handoff-related reasons); and 2) the collected channel information is used to guide the WiFi interface 18 to scan a channel which is predetermined to have some certain best "qualities", such as an AP 30 with the highest data rate and/or the strongest signal. The time needed for WiFi channel scanning can thus be reduced, while increasing the probability of the MCD 10 successfully associating an AP 30. Note that in conventional WiFi scanning it may be necessary to scan all channels (e.g., all 11 channels) during each scanning procedure, whereas by using the exemplary embodiments of this invention it may be possible for the WiFi interface 18 to scan but one channel.

The exemplary embodiments of this invention enable the WLAN module 18 to operate with (select to) a best channel (or prioritized channel list). The use of the low power receiver module 20 and the analysis of the RSSI sequence do not in and of itself determine the AP 30 SSID, as the channel need not be demodulated. The evaluation metric of a particular channel includes at least one or more of the number of APs 30 operating in that channel, the signal strength of those APs 30, and a maximum data rate of those APs 30.

The exemplary embodiments of this invention thus provide a number of technical effects and advantages, including a power-saving AP detection technique that enables the MCD 10 to associate with an AP 30 in an energy efficient manner. Based on a statistical analysis of a sampled channel energy sequence, the MCD 10 is enabled to determine information including at least the number of APs 30 operating within communication range, the beacon frame duration, and the beacon frame signal strength. Using all or some of this information the MCD 10 can make an informed determination as to whether to power on the higher power WLAN interface module 18.

Based on the foregoing it should be apparent that the exemplary embodiments of this invention provide a method, apparatus and computer program(s) to reduce the power required to perform AP 30 discovery and association.

Figure 7 is a logic flow diagram that illustrates the operation of a method, and a result of execution of computer program instructions, in accordance with the exemplary embodiments of this invention. In accordance with these exemplary embodiments a method performs, at Block 7A, a step of sampling energy of a particular radio channel within a time window to obtain a plurality of received signal strength indications. At Block 7B there is a step of analyzing the plurality of received signal strength indications using a procedure that is capable of finding a periodic signal in a sampled sequence containing noise. At Block 7C there is a step of associating at least one peak output from the folding algorithm with a potential beacon transmission from at least one access point operating in the particular radio channel. At Block 7D there is a step of turning on a wireless local area network radio to scan the particular channel to detect the at least one access point.

The various blocks shown in Figure 7 may be viewed as method steps, and/or as operations that result from operation of computer program code, and/or as a plurality of coupled logic circuit elements constructed to carry out the associated function(s).

In general, the various exemplary embodiments may be implemented in hardware or special purpose circuits, software, logic or any combination thereof. For example, some aspects may be implemented in hardware, while other aspects may be implemented in firmware or software which may be executed by a controller, microprocessor or other computing device, although the invention is not limited thereto. While various aspects of the exemplary embodiments of this invention may be illustrated and described as block diagrams, flow charts, or using some other pictorial representation, it is well understood that these blocks, apparatus, systems, techniques or methods described herein may be implemented in, as non-limiting examples, hardware, software, firmware, special purpose circuits or logic, general purpose hardware or controller or other computing devices, or some combination thereof.

The exemplary embodiments of this invention also pertain at least in part to an apparatus that comprises means for sampling energy of a particular radio channel within a time window to obtain a plurality of received signal strength indications; means for analyzing the plurality of received signal strength indications using a procedure that is capable of finding a periodic signal in a sampled sequence containing noise; means for associating at least one peak output from the folding algorithm with a potential beacon transmission from at least one access point operating in the particular radio channel; and means for turning on a wireless local area network radio to scan the particular channel to detect the at least one access point.

It should thus be appreciated that at least some aspects of the exemplary embodiments of the inventions may be practiced in various components such as integrated circuit chips and modules, and that the exemplary embodiments of this invention may be realized in an apparatus that is embodied as an integrated circuit. The integrated circuit, or circuits, may comprise circuitry (as well as possibly firmware) for embodying at least one or more of a data processor or data processors, a digital signal processor or processors, baseband circuitry and radio frequency circuitry that are configurable so as to operate in accordance with the exemplary embodiments of this invention. For example, the various MCD 10 components shown in Figure 1 may all be embodied in a single chip set, or in other embodiments the low power receiver module 20 may be embodied separately from the chip set containing all or at least some of the other MCD 10 components. In this latter case the chip set can include at least one input pin for receiving an analog output of the low power receiver module 20, and signal processing it (e.g., digitizing the signal) in the chip set, or the low power receiver module 20 may be constructed to output a single or multiple-bit digitized signal indicating the energy received in the various channels.

Thus, it can be appreciated that various modifications and adaptations to the foregoing exemplary embodiments of this invention may become apparent to those skilled in the relevant arts in view of the foregoing description, when read in conjunction with the accompanying drawings. However, any and all modifications will still fall within the scope of the non-limiting and exemplary embodiments of this invention.

For example, while the exemplary embodiments have been described above in the context of the IEEE 802.11b, IEEE 802.11g and IEEE 802.15 TG4 wireless communication systems, it should be appreciated that the exemplary embodiments of this invention are not limited for use with only these particular type of wireless communication systems, and that they may be used to advantage in and with other wireless communication systems.

In addition, and as was pointed out above, other procedures and algorithms, other than the folding algorithm, may be used to detect the presence of the energy of the access point beacon transmission in the sampled channel energy.

It should be noted that the terms "connected," "coupled," or any variant thereof, mean any connection or coupling, either direct or indirect, between two or more elements, and may encompass the presence of one or more intermediate elements between two elements that are "connected" or "coupled" together. The coupling or connection between the elements can be physical, logical, or a combination thereof. As employed herein two elements may be considered to be "connected" or "coupled" together by the use of one or more wires, cables and/or printed electrical connections, as well as by the use of electromagnetic energy, such as electromagnetic energy having wavelengths in the radio frequency region, the microwave region and the optical (both visible and invisible) region, as several non-limiting and non-exhaustive examples.

Further, the various names used for the described parameters are not intended to be limiting in any respect, as these parameters may be identified by any suitable names. Further, the formulas and expressions that use these various parameters may differ from those expressly disclosed herein. Further, the various names assigned to different components (e.g., WLAN module), signals (e.g., beacon), and so forth are not intended to be limiting in any respect, as these various components and signals may be identified by any suitable names.

Furthermore, some of the features of the various non-limiting and exemplary embodiments of this invention may be used to advantage without the corresponding use of other features. As such, the foregoing description should be considered as merely illustrative of the principles, teachings and exemplary embodiments of this invention, and not in limitation thereof.

WHAT IS CLAIMED IS:

1. A method, comprising:

sampling energy of a particular radio channel within a time window to obtain a plurality of received signal strength indications;

analyzing the plurality of received signal strength indications using a procedure that is capable of finding a periodic signal in a sampled sequence containing noise;

associating at least one peak output from the procedure with a potential beacon transmission from at least one access point operating in the particular radio channel; and

turning on a wireless local area network radio to scan the particular channel to detect the at least one access point.

2. The method of claim 1, where sampling is performed periodically.

3. The method of claim 1, where the time window has a duration that is predetermined to sample a plurality of beacon transmissions.

4. The method of claim 1, where sampling comprises obtaining a plurality of consecutive samples at a sampling rate, and where the sampling rate is predetermined to sample a single beacon transmission a plurality of times.

5. The method of claim 4, further comprising determining a data rate associated with the beacon transmission based on a number of number of consecutive samples of the single beacon transmission.

6. The method of claim 1, where sampling uses a radio receiver that is separate from the wireless local area network radio, and that has an operating power requirement that is less than an operating power requirement of the wireless local area network radio.

7. The method of claim 1, where the wireless local area network radio is compatible with one of: IEEE 802.11 operation, and another wireless local area network radio compatible with the transmission of periodic beacons.

8. The method of claim 6, where the radio receiver used for sampling is compatible with one of Bluetooth Low Energy, Zigbee, IEEE 802.15.4 and another short range radio reception technology.

9. The method of claim 6, where the wireless local area network radio and the radio receiver used for sampling both operate at about 2.4 GHz.

10. The method of claim 6, where the wireless local area network radio and the radio receiver used for sampling operate in the same radio spectrum but with different channelizations.

11. The method of claim 6, further comprising turning off the radio receiver used for sampling at the end of the time window.

12. The method as in claim 1, where the procedure that is capable of finding a periodic signal in a sampled sequence containing noise comprises a folding algorithm.

13. An apparatus, comprising:

a processor; and

a memory including computer program code, where the memory and computer program code are configured to, with the processor, cause the apparatus at least to perform,

sampling energy of a particular radio channel within a time window to obtain a plurality of received signal strength indications;

analyzing the plurality of received signal strength indications using a procedure that is capable of finding a periodic signal in a sampled sequence containing noise;

associating at least one peak output from the procedure with a potential beacon transmission from at least one access point operating in the particular radio channel; and

turning on a wireless local area network radio to scan the particular channel to detect the at least one access point.

14. The apparatus of claim 13, where the time window has a duration that is predetermined to sample a plurality of beacon transmissions.

15. The apparatus of claim 13, where sampling comprises obtaining a plurality of consecutive samples at a sampling rate, and where the sampling rate is predetermined to sample a single beacon transmission a plurality of times.

16. The apparatus of claim 15, further comprising determining a data rate associated with the beacon transmission based on the number of consecutive samples of the single beacon transmission.

17. The apparatus of claim 13, where the apparatus further comprises a radio receiver used for sampling that is separate from the wireless local area network radio, and that has an operating power requirement that is less than an operating power requirement of the wireless local area network radio.

18. The apparatus of claim 13, where the wireless local area network radio is compatible with one of: IEEE 802.11 operation, and another wireless local area network radio compatible with the transmission of periodic beacons.

19. The apparatus of claim 17, where the radio receiver used for sampling is compatible with one of Bluetooth Low Energy, Zigbee, IEEE 802.15.4 and another short range radio reception technology.

20. The apparatus of claim 17, where the wireless local area network radio and the radio receiver used for sampling both operate at about 2.4 GHz.

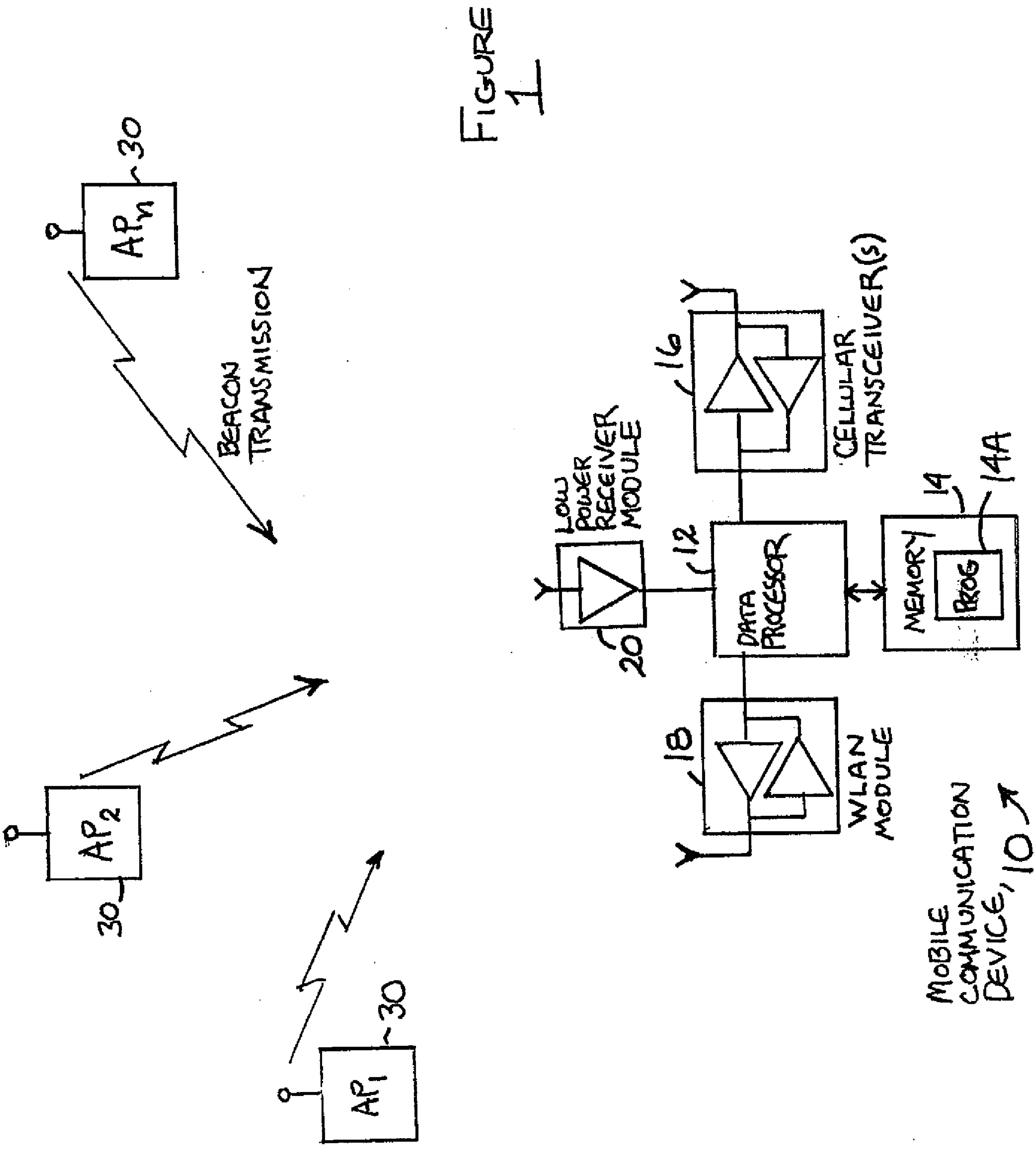
21. The apparatus of claim 17, where the wireless local area network radio and the radio receiver used for sampling operate in the same radio spectrum but with different channelizations.

22. The apparatus of claim 17, further comprising turning off the radio receiver used for sampling at the end of the time window.

23. The apparatus as in claim 13, where the procedure that is capable of finding a periodic signal in a sampled sequence containing noise comprises a folding algorithm.

24. The apparatus of claim 13, further comprising a radio module configured for operation with at least one cellular wireless communication system.

25. The apparatus of claim 13, embodied in a chip set, where the radio receiver used for sampling is one of contained within the chip set or is separate from the chip set.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AP$_2$
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AP$_1$
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LOW POWER RECEIVER MODULE
20
12
DATA PROCESSOR
16
CELLULAR TRANSCEIVER(S)
18
WLAN MODULE
MEMORY
14
PROG
14A
MOBILE COMMUNICATION DEVICE, 10

FIGURE 1

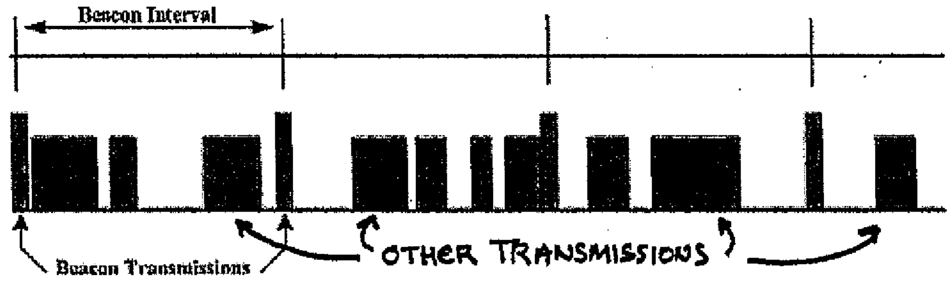

FIGURE 2

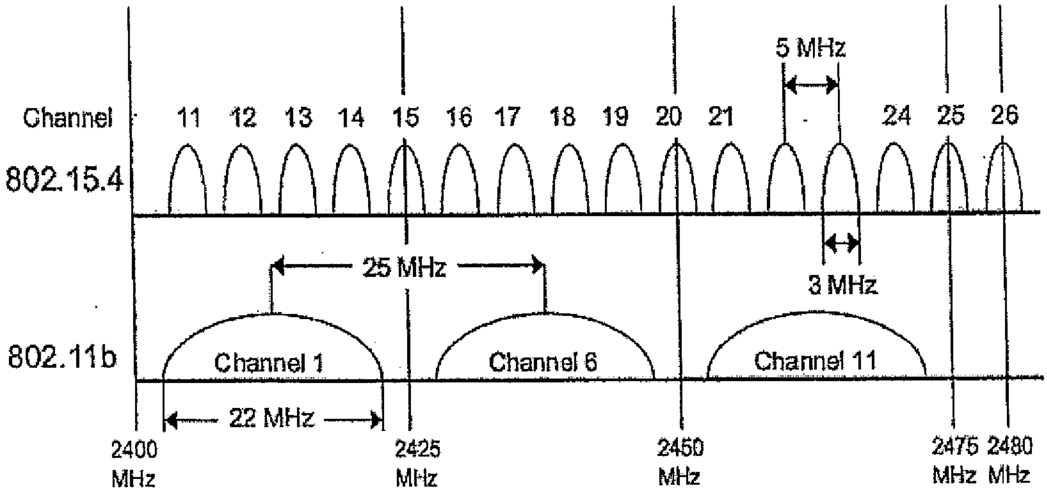

FIGURE 3

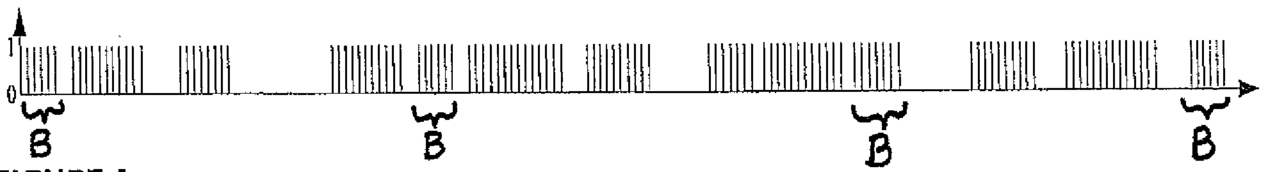

FIGURE 4

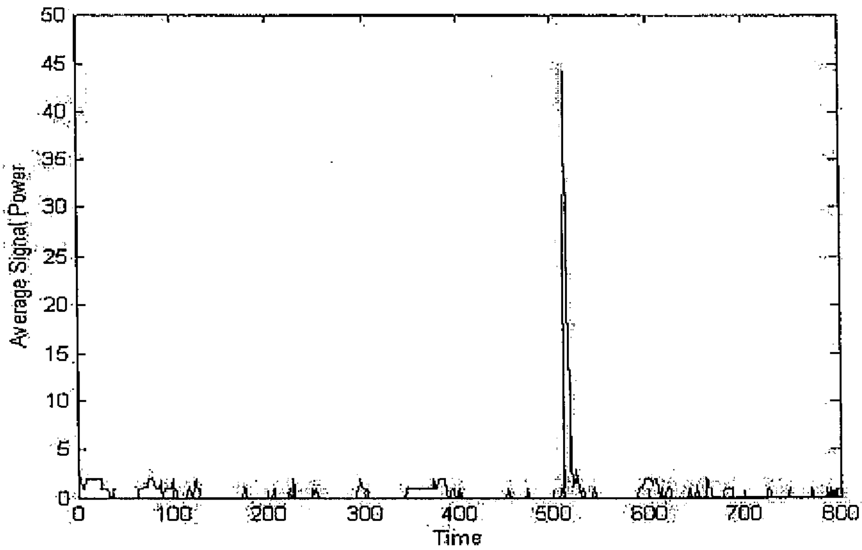

FIGURE 5

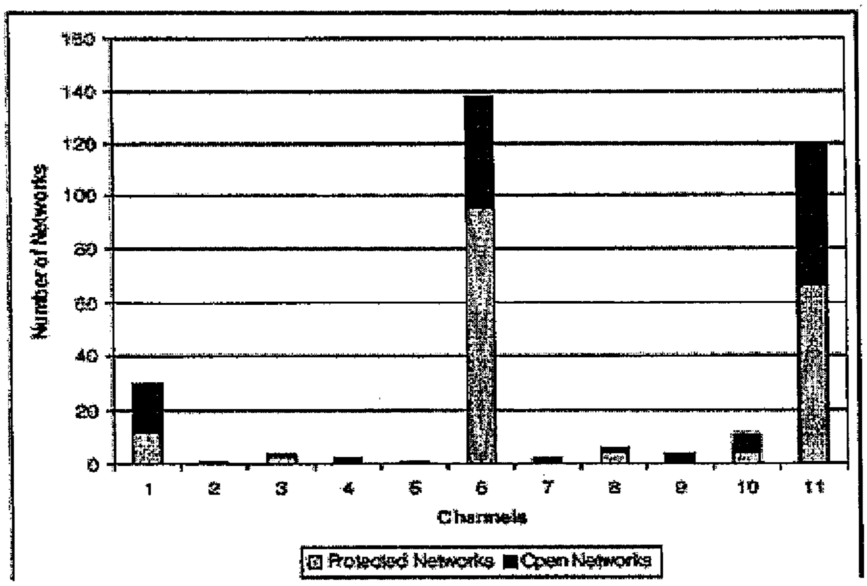

FIGURE 6

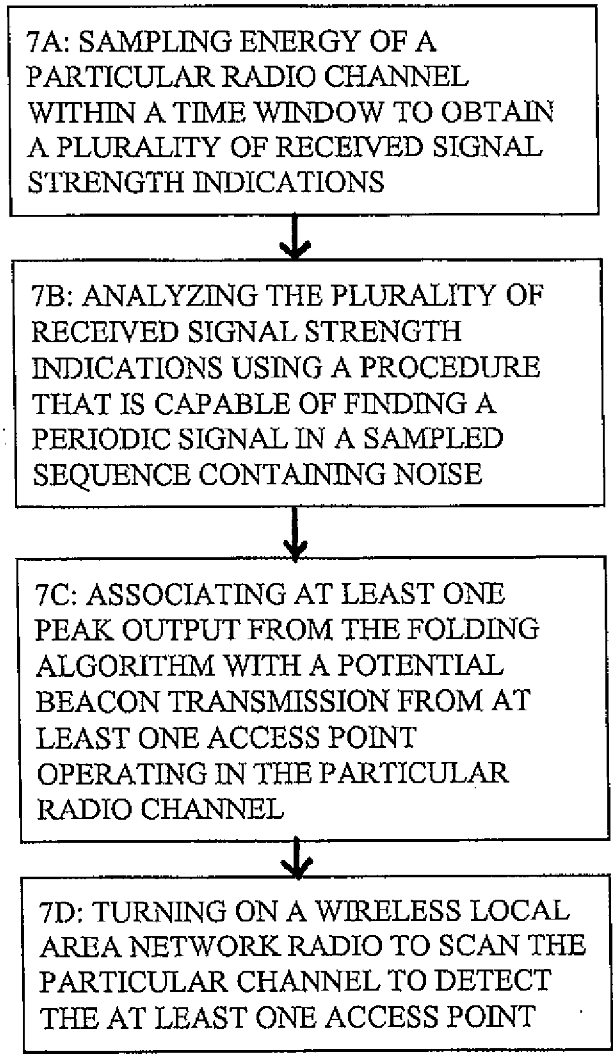
7A: SAMPLING ENERGY OF A PARTICULAR RADIO CHANNEL WITHIN A TIME WINDOW TO OBTAIN A PLURALITY OF RECEIVED SIGNAL STRENGTH INDICATIONS
7B: ANALYZING THE PLURALITY OF RECEIVED SIGNAL STRENGTH INDICATIONS USING A PROCEDURE THAT IS CAPABLE OF FINDING A PERIODIC SIGNAL IN A SAMPLED SEQUENCE CONTAINING NOISE
7C: ASSOCIATING AT LEAST ONE PEAK OUTPUT FROM THE FOLDING ALGORITHM WITH A POTENTIAL BEACON TRANSMISSION FROM AT LEAST ONE ACCESS POINT OPERATING IN THE PARTICULAR RADIO CHANNEL
7D: TURNING ON A WIRELESS LOCAL AREA NETWORK RADIO TO SCAN THE PARTICULAR CHANNEL TO DETECT THE AT LEAST ONE ACCESS POINT

FIGURE 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2009/075551

A. CLASSIFICATION OF SUBJECT MATTER

H04W 48/20 (2009.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: H04W, H04B, H04Q, H04L

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)

CPRSABS, CPDIABS, CPPABS, CNTXT, CNKI, WPI, EPODOC: access w point, AP, WLAN, RSSI, beacon, detect+, folding, peak, periodic.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN101483894A (UNIV BEIJING JIAOTONG) 15 Jul. 2009 (15.07.2009) the whole document	1-25
A	CN101282264A (QUALCOMM INC) 08 Oct. 2008 (08.10.2008) the whole document	1-25
A	CN101557625A (UNIV NANJING) 14 Oct. 2009 (14.10.2009) the whole document	1-25
A	GB2435983A (GIGA BYTE TECH CO LTD) 12 Sep. 2007 (12.09.2007) the whole document	1-25

☐ 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 application or patent but published on or after the international filing date

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

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

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

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

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

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

"&"document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 Sep. 2010 (10.09.2010)	**23 Sep. 2010 (23.09.2010)**

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2009/075551

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN101483894A	15.07.2009	NONE	
CN101282264A	08.10.2008	US2004176024A1	09.09.2004
		WO2004077753A2	10.09.2004
		EP1597869A2	23.11.2005
		BRPI0407770A	01.03.2006
		MXPA05009042A	23.11.2005
		CN1754345A	29.03.2006
		KR20050104388A	02.11.2005
		JP2006518975T	17.08.2006
		US7146130B2	05.12.2006
		INCHENP200502004E	31.08.2007
		CN100380882C	09.04.2008
		MX256140B	09.04.2008
		TW200507523A	16.02.2005
		CA2516923A1	10.09.2004
		US2007093201A1	26.04.2007
		HK1089578A1	13.02.2009
		US7778593B2	17.08.2010
CN101557625A	14.10.2009	NONE	
GB2435983A	12.09.2007	GB2435983B	10.02.2010