A radio communication device includes a two-way communications component having a first receiver and transmitter, an interface for receiving one or more sensor signals based on sensor-acquired data that is indicative of a predetermined condition, electronic components, and a second receiver. The second receiver activates the two-way communications component from a dormant state upon receipt by the second receiver of a wake-up broadcast that includes a wake-up identifier of the data communication device. The wake-up broadcast includes a data construct including a wake-up identifier and the auxiliary information. The auxiliary information is received and recorded by the data communication device via the second receiver with the two-way communications component remaining in the dormant state. The device operates in two states, the device enters a first state from a second state upon receiving one or more sensor signals based on sensor-acquired data that is indicative of a predetermined condition.
FIG. 5

Range of Broadcast
WU[01050107] by Gateway G1

FIG. 6

Range of Broadcast
WU[01051013] by Node N1
Wake-Up Broadcast (WU) Data Construct

**Fig. 7**

Wake-Up Broadcast (WU) Data Construct

**Fig. 8**

Wake-Up Broadcast (WU) Data Construct

**Fig. 9**
### Exemplary Table of Wake-Up Identifiers for Node N2

<table>
<thead>
<tr>
<th>Wake-Up Identifier</th>
<th>Status</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0101</td>
<td>Inactive</td>
<td>Node N1 with Unique ID 101</td>
</tr>
<tr>
<td>0102</td>
<td>Active</td>
<td>Node N2 with Unique ID 102</td>
</tr>
<tr>
<td>0103</td>
<td>Inactive</td>
<td>Node N3 with Unique ID 103</td>
</tr>
<tr>
<td>0104</td>
<td>Inactive</td>
<td>Node N4 with Unique ID 104</td>
</tr>
<tr>
<td>0105</td>
<td>Inactive</td>
<td>Node N5 with Unique ID 105</td>
</tr>
</tbody>
</table>

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0801</td>
<td>Inactive</td>
<td>Gateway G1 with Unique ID 801</td>
</tr>
<tr>
<td>0802</td>
<td>Inactive</td>
<td>Gateway G2 with Unique ID 802</td>
</tr>
<tr>
<td>0803</td>
<td>Inactive</td>
<td>Gateway G3 with Unique ID 803</td>
</tr>
</tbody>
</table>

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>Active</td>
<td>Wake-Up (generic to all nodes)</td>
</tr>
<tr>
<td>1001</td>
<td>Inactive</td>
<td>Common Designation: Circle</td>
</tr>
<tr>
<td>1002</td>
<td>Active</td>
<td>Common Designation: Polygon</td>
</tr>
<tr>
<td>1003</td>
<td>Inactive</td>
<td>Common Designation: Rectangle (subset of Polygon)</td>
</tr>
<tr>
<td>1004</td>
<td>Inactive</td>
<td>Common Designation: Square (subset of Rectangle)</td>
</tr>
<tr>
<td>1005</td>
<td>Active</td>
<td>Common Designation: Triangle (subset of Polygon)</td>
</tr>
<tr>
<td>1006</td>
<td>Active</td>
<td>Common Designation: Isosceles Triangle (subset of Triangle)</td>
</tr>
</tbody>
</table>

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3001</td>
<td>Active</td>
<td>Node Attribute: Communications with gateway available</td>
</tr>
<tr>
<td>3002</td>
<td>Active</td>
<td>Node Attribute: Direct Communications with gateway</td>
</tr>
</tbody>
</table>

**Fig. 10**
**Exemplary Table of Wake-Up Identifiers for Gateway G1**

<table>
<thead>
<tr>
<th>Wake-Up Identifier</th>
<th>Status</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0101</td>
<td>Inactive</td>
<td>Node N1 with Unique ID 101</td>
</tr>
<tr>
<td>0102</td>
<td>Inactive</td>
<td>Node N2 with Unique ID 102</td>
</tr>
<tr>
<td>0103</td>
<td>Inactive</td>
<td>Node N3 with Unique ID 103</td>
</tr>
<tr>
<td>0104</td>
<td>Inactive</td>
<td>Node N4 with Unique ID 104</td>
</tr>
<tr>
<td>0105</td>
<td>Inactive</td>
<td>Node N5 with Unique ID 105</td>
</tr>
<tr>
<td>0801</td>
<td>Active</td>
<td>Gateway G1 with Unique ID 101</td>
</tr>
<tr>
<td>0802</td>
<td>Inactive</td>
<td>Gateway G2 with Unique ID 102</td>
</tr>
<tr>
<td>0803</td>
<td>Inactive</td>
<td>Gateway G3 with Unique ID 103</td>
</tr>
<tr>
<td>1000</td>
<td>Active</td>
<td>Wake-Up (generic to all nodes)</td>
</tr>
<tr>
<td>1001</td>
<td>Active</td>
<td>Common Designation: Circle</td>
</tr>
<tr>
<td>1002</td>
<td>Active</td>
<td>Common Designation: Polygon</td>
</tr>
<tr>
<td>1003</td>
<td>Active</td>
<td>Common Designation: Rectangle (subset of Polygon)</td>
</tr>
<tr>
<td>1004</td>
<td>Active</td>
<td>Common Designation: Square (subset of Rectangle)</td>
</tr>
<tr>
<td>1005</td>
<td>Active</td>
<td>Common Designation: Triangle (subset of Polygon)</td>
</tr>
<tr>
<td>1006</td>
<td>Active</td>
<td>Common Designation: Isosceles Triangle (subset of Triangle)</td>
</tr>
</tbody>
</table>

*FIG. 11*
FIG. 12
FIG. 13
FIG. 14
FIG. 15
FIG. 16
FIG. 17
\[ t = t_f \]

**FIG. 18**
DETERMINING PRESENCE OF A RADIO FREQUENCY COMMUNICATION DEVICE

CROSS REFERENCE TO RELATED APPLICATIONS


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BACKGROUND

[0004] Wireless ad hoc networks comprise nodes that communicate without central control or wired infrastructure. Such networks may have dynamic, randomly-changing, multihop topologies composed of wireless data communication links between the nodes. Ad hoc networks are advantageous because they are inexpensive, fault-tolerant, and flexible.

[0005] The present invention relates to improvements in wireless ad hoc networks and, in particular, improvements in such networks that utilize common designation networking.

[0006] In another aspect, conventional systems for tracking and/or monitoring assets (herein generally referred to as “asset tracking systems”) utilize wireless tags that generally respond to any broadcast that is made. The wireless tags usually are passive, and the responses that the passive wireless tags make are often referred to as “chirps.”

[0007] More sophisticated asset tracking systems utilize semi-passive wireless tags and/or active wireless tags. A semi-passive wireless tag includes an internal power source for transmitting, and an active wireless tag includes an internal power source for both receiving and transmitting. Semi-passive and active wireless tags generally have greater capabilities than passive wireless tags due to the internal power sources. Of course, power consumption is always a concern when a wireless tag includes an internal power source, since the internal power supply limits the useful life of the wireless tag, after which time maintenance is required (e.g., replacement of the internal power source).

[0008] In improved asset tracking systems, such as those disclosed in the above patent applications and patents that have been incorporated herein by reference, a wireless tag responds to a broadcast if the broadcast includes a common designation matching a common designation of the wireless tag. Such a common designation may comprise, for example, an “asset class” associated with the wireless tag. Ad hoc networks further may be created based on such classes, which ad hoc networks are referred to as “class based” networks.

[0009] Class based networks (and common designation networks in general) are beneficial because, in such networks, a communication device, such as a wireless tag, generally only transmits a response to a broadcast if the broadcast includes a class (or common designation) that matches a class (or common designation) of that communication device. Indeed, in a communication device employing a wakeup sequence of one or more of the patent references incorporated herein by reference, such communication device does not even process a broadcast once it is determined that the broadcast fails to include a matching class of the communication device. Consequently, the internal power supply of a semi-passive or active communication device is not drained by needless processing and/or responses to broadcasts.

[0010] In asset tracking systems, it often is important to know the physical location of an asset. This could include knowing where the asset is within a limited physical area, such as a warehouse; this also could include knowing where
the asset is within several different warehouses in several different geographical locations, as well as where the asset is during transit between such locations.

[0011] In a conventional asset tracking system in which communication devices comprising semi-passive or active radios are placed on the assets, a conventional method for acquiring visibility of the assets includes broadcasting within an area at regular intervals to solicit responses from all of the radios within the area. The responses from the radios reveal the radios, and thus the assets, that are in the area.

[0012] This method is not advantageous because the regular, repetitive broadcasts result in an unnecessary power drain of the responding radios. Interference also can occur if a large number of radios respond at the same time, thereby making it difficult to accurately identify all of the radios within the area that respond to the broadcast.

[0013] In an alternative conventional method, a timer is included with each radio and the radio is configured to transmit at periodic intervals as a function of the timer. The radio thereby alerts the tracking system as to the whereabouts of the radio and, thus, the asset with which it is associated. By including timers with each radio, the radios may transmit at differing times in order to avoid unnecessary interference. A radio also can be set to sleep between intervals and to be woken by the timer for making its regular transmissions. This increases the useful life of the radios because the radios do not consume power by actively listening for broadcasts while sleeping.

[0014] This alternative method permits determinations as to the delivery and continued presence of an asset at a particular area. Nevertheless, this alternative method does include drawbacks. For instance, by using timers, the radios are inaccessible by the asset tracking system during the sleep periods. Another drawback is that the radios automatically wake and transmit without regard for their location and without regard for whether the transmission is actually warranted or even desired. In this respect, during transportation on a plane, a radio may awaken and transmit, which may cause unwanted interference with the operation of the airplane. Preprogrammed transmission at regular intervals also may reveal the presence of the asset to unauthorized persons snooping for such radio transmissions.

[0015] Accordingly, better asset tracking systems and methods are desired that minimize unnecessary power consumption and that reduce unnecessary transmissions by communication devices associated with assets.

SUMMARY

[0016] The present invention broadly relates to improved common designation networking and common designation networks and, in particular, to wireless communications utilizing improved common designation networking and common designation networks within wireless ad hoc networking environments.

[0017] Broadly described, the present invention includes many aspects and features.

[0018] The invention relates to ad hoc wireless networking utilizing a data communication device as a node of the network, wherein the data communication device includes both a two-way communications component comprising a first receiver and transmitter, and a second receiver, and wherein the second receiver activates the two-way communications component from a dormant state upon receipt by the second receiver of a wake-up broadcast that includes a wake-up identifier of the data communication device.

[0019] In accordance with an aspect of the invention, a method of providing information via the second receiver—which information is auxiliary to the wake-up of the two-way data communications component—includes transmitting a wake-up broadcast. The wake-up broadcast is capable of being received by the second receiver if in broadcast range, and the wake-up broadcast includes a data construct comprising a wake-up identifier and the auxiliary information. The wake-up identifier may or may not be the wake-up identifier of the data communication device. Nevertheless, the auxiliary information is received and recorded by the data communication device via the second receiver with the two-way communications component remaining in the dormant state.

[0020] In another aspect of the invention, a method of receiving information by the data communication device via the second receiver—which information is auxiliary to the wake-up of two-way communications component—includes the steps of: receiving a wake-up broadcast, the wake-up broadcast including a data construct comprising a wake-up identifier and the auxiliary information; storing the auxiliary information in memory of the data communication device; and activating the two-way communications component from a dormant state, in response to receipt of the wake-up broadcast, if a wake-up identifier of the data communications device is found in the wake-up broadcast, and not activating the two-way communications component from a dormant state, in response to receipt of the wake-up broadcast, if a wake-up identifier of the data communications device is not found in the wake-up broadcast.

[0021] In features of these aspects, the auxiliary information comprises a node identification from which the wake-up broadcast is transmitted; the auxiliary information comprises a transmission count regarding wake-up broadcasts transmitted by a node; the auxiliary information comprises an encryption key; the auxiliary information comprises application specific data; and/or the auxiliary information comprises an indication of the status of a sensor.

[0022] In additional features, the second receiver draws substantially less current while listening for a wake-up broadcast than the two-way communications component would draw while listening for a wake-up broadcast; the second receiver draws less current while listening for a wake-up broadcast than the two-way communications component would draw while listening for a wake-up broadcast, the difference in current draw being at least an order of magnitude (such as milliamps versus microamps); and/or the second receiver utilizes a stepped wake-up sequence based on at least two criteria, and wherein the last criteria before awakening the two-way communications component comprises identifying a wake-up identifier of the data communication device in the wake-up broadcast.

[0023] In another feature, of these aspects, the second receiver is part of a wake-up transceiver, and the wake-up transceiver further comprises a second transmitter of the data communication device that is configured to transmit a wake-up broadcast for receipt by another wake-up receiver of another data communication device.

[0024] In various implementations of these aspects, the data communication device is a node in a common desig-
nation wireless ad hoc sensor network; and/or the data communication device is a node in a class based wireless ad hoc network.

[0025] In yet additional features of these aspects, the auxiliary information is used by the data communication device for facilitating network communications by the two-way communications component. In this regard, the auxiliary information may include network information that is reviewed by the data communication device when determining network paths for communicating with a desired node, whereby network communications are facilitated. The network information may include: the identification of one or more nodes that are within direct communication range of the data communication device; the identification of a gateway node that is within direct communication range of the data communication device; the identification of one or more nodes from which wake-up broadcasts have been received, either directly or indirectly, by the second wake-up receiver; and/or the identification of one or more common designations from which wake-up broadcasts have been received, either directly or indirectly, by the second wake-up receiver.

[0026] Another aspect of the invention includes computer executable instructions stored in a computer readable medium for performing any of the foregoing aspects and features, including any combinations thereof.

[0027] In yet another aspect of the invention, an ad hoc wireless network system includes an ad hoc wireless network utilizing a plurality of data communication devices as nodes of the network; wherein each data communication device includes both a two-way communications component, comprising a first receiver and transmitter, and a second receiver, wherein the second receiver activates the two-way communications component from a dormant state upon receipt by the second receiver of a wake-up broadcast that includes a wake-up identifier of the data communication device; and wherein information is provided via each second receiver, which information is auxiliary to the wake-up of the two-way communications component, by transmitting a wake-up broadcast, which the second receiver is capable of receiving, that includes a data construct comprising a wake-up identifier and the auxiliary information.

[0028] In still another aspect of the invention, a data communication device for utilization as a node in an ad hoc wireless network includes a two-way communications component comprising a first receiver and transmitter; and a second receiver, wherein the second receiver activates the two-way communications component from a dormant state upon receipt by the second receiver of a wake-up broadcast that includes a wake-up identifier of the data communication device; wherein information is provided via the second receiver, which information is auxiliary to the wake-up of the two-way communications component, by transmitting a wake-up broadcast, which the second receiver is capable of receiving, that includes a data construct comprising a wake-up identifier and the auxiliary information.

[0029] Additional aspects and features relate to, and are described in, the context of asset tracking systems, the present invention is not limited to use only in asset tracking systems, as will become apparent from the following summaries and detailed descriptions of aspects, features, and one or more embodiments of the present invention. For instance, one or more aspects of the present invention may be utilized to determine the presence or arrival of a communication device within an area independent of any asset and/or independent of any asset tracking system. The present invention also is not limited to use in common designation or class-based networks, although in preferred embodiments common designation or class-based networks are used. Indeed, the present application may beneficially be used in asset tracking as well as sensor monitoring, hazmat monitoring, first responder scenarios, military activities and situations, mobile phone applications, and automobile dealer key tracking systems.

[0030] Accordingly, an aspect of the present invention relates to a radio frequency communication device that includes a receiver configured to receive radio frequency transmissions; a transmitter configured to make radio frequency transmissions; an interface for receiving a signal from a sensor (hereinafter “sensor signal”); and electronic components. In accordance with this aspect of the invention, the electronic components are arranged and configured such that the radio frequency communication device operates in at least two states.

[0031] In the first state, the radio frequency communication device responds to a radio frequency transmission that is received by the receiver and that includes data representative of an inquiry as to the presence of radio frequency communication devices within an area. The “data representative of an inquiry as to the presence of radio frequency communication devices within an area” simply may be a predefined value in a particular format within the broadcast in accordance with a predefined protocol. A radio frequency transmission that includes such data is sometimes referred to herein as a “Present Broadcast.” The response to the Present Broadcast is made by the radio frequency communication device by making a radio frequency transmission with the transmitter that includes an identification of the radio frequency communication device. A radio frequency transmission that includes an identification of the radio frequency communication device making the transmission, and that is made in response to a Present Broadcast, is sometimes referred to herein as a “Present Response.”

[0032] In the second state, the radio frequency communication device does not respond to a Present Broadcast with a Present Response; specifically, no response to a Present Broadcast comprising a radio frequency transmission is made with the transmitter that includes an identification of the radio frequency communication device, and preferably, no response to a Present Broadcast comprising a radio frequency transmission is made at all, whether including an identification of the radio frequency communication device or otherwise.

[0033] In further accordance with this aspect of the invention, the electronic components are arranged and configured such that the radio frequency communication device enters the second state from the first state upon responding to a Present Broadcast with a Present Response. The electronic components further are arranged and configured such that the radio frequency communication device enters the first state from the second state upon receiving, through the interface, a sensor signal based on sensor-acquired data that is indicative of a predetermined condition. The sensor signal itself may include the sensor-acquired data or may be representative of the sensor-acquired data and may indicate, for example, a state of the sensor. In any event, such sensor signal is deemed to provide “sensor-acquired information” through the interface.
In a feature of this aspect, the first and second states relate only to whether the communication device responds to a Present Broadcast. Thus, the communication device otherwise remains responsive to other broadcasts in general and/or remains responsive to transmissions directed to the device. For example, in class-based networks, the communication device preferably remains responsive to any transmission including a class to which it is a member, whether the communication device is in the first state or the second state. Such transmission to the communication device may relate to a change in sensor states; maintenance of the communication device (e.g., checking the status of the internal power supply); or enabling or disabling of certain features or capabilities of the communication device (including the practicing of the present invention). In an alternative—and less preferred—feature, the first and second states relate not only to whether the communication device responds to a Present Broadcast, but whether the communication device responds to any broadcast at all. In this respect, when the communication device is in the second state, the communication device may not respond to any broadcasts at all.

In yet another feature of this aspect, the electronic components are further configured such that the radio frequency communication device makes a radio frequency transmission upon receiving, through the interface, sensor-acquired information that indicates a predetermined condition.

In another feature of this aspect, the radio frequency communication device further includes a computer processor that processes received radio frequency transmissions and received sensor-acquired information. The computer processor preferably affects state changes of the radio frequency communication device as a function of received radio frequency transmissions and received sensor-acquired information.

In still another feature, the communication device enters the first state from the second state after a predetermined period of time has transpired according to a timer of the communication device. This feature is beneficial, for example, if a sensor associated with a radio frequency communication device fails and if the radio frequency communication device would not otherwise enter the first state from the second state. In this regard, the time period before the radio frequency communication device enters, by default, the first state from the second state may be a significant period of time.

In still another feature, the communication device enters the first state from the second state after a predetermined number of failed attempts to communicate with a server have occurred. This feature is beneficial, for example, in identifying radio frequency communication devices in a certain area that are having technical difficulties in their communications. In still another feature, the radio frequency communication device enters the first state from the second state upon receipt, via the receiver of radio frequency communication device, of an instruction to enter the first state. The instruction may be specific to a particular radio frequency communication device or generic to a plurality of radio frequency communication devices. Furthermore, a special common designation, such as a special class, may be utilized whereby a broadcast to such common designation would instruct radio frequency communication device having that common designation to enter the first state. This feature is beneficial, for example, if a sensor associated with a radio frequency communication device fails and if the radio frequency communication device would not otherwise enter the first state from the second state. This enables, for example, a server to look for a radio frequency communication device within a particular area.

Another aspect of the invention relates to a method performed by a radio frequency communication device. The method includes: the first steps of responding to a Present Broadcast with a Present Response and then not responding to any further Present Broadcasts; and, repeating the first steps upon receiving, through an interface of the radio frequency communication device, sensor-acquired information that is indicative of a predetermined condition. Thus, after receiving such sensor-acquired information, the radio frequency communication device does, in fact, respond to the next Present Broadcast.

In a feature of this aspect of the invention, the method further includes the step of making a radio frequency transmission with the transmitter of the radio frequency communication device upon receiving, through an interface of the radio frequency communication device, the sensor-acquired information indicative of the predetermined condition.

In accordance with this and other aspects of the invention, the predetermined condition may comprise movement of the radio frequency communication device; a change, exceeding a threshold, with respect to the location of the radio frequency communication device as determined based on GPS data; and/or a temperature associated with the radio frequency communication device exceeding a predetermined threshold. With further respect to location, for example, the data from the GPS receiver may be compared against a range of x-y coordinates for “geo fencing” of the communication device (e.g., 89.2412< x<89.4522 and 145. 2332<y<145.8772), with a predetermined condition being triggered by the GPS data that indicates the communication device being outside of a predefined geographical area. An example of this is described below with regard to FIGS. 12-19.

In further accordance with the invention, the predetermined condition may comprise a change in state of a sensor associated with a radio frequency communication device and the sensor may or may not indicate movement from an area. Such a state change could indicate, for example, the breaking of a magnetic seal or other seal of a container wherein the sensor monitors the seal of the container. The container could be, for example, a hazardous waste container or an international shipping container. In such case, the Present Broadcast could be used to reveal those containers for which the seals have been broken.

In another feature of the invention, the radio frequency communication device may comprises a node in one or more common designation networks. In this respect, the data representative of a general inquiry as to the presence of radio frequency communication devices may be a predefined common designation. Indeed, the data representative of a general inquiry as to the presence of radio frequency communication devices may be a common designation of “present.”

In a related feature, the radio frequency communication device is associated with an asset being tracked in an asset tracking system. The asset tracking system may be a class-based asset tracking system, and the data represen-
tative of a general inquiry as to the presence of radio frequency communication devices may be a predefined class designation. Indeed, the data representative of a general inquiry as to the presence of radio frequency communication devices may be a class designation of “present.”

[0045] It will be appreciated that, in accordance with one or more aspects, determinations can be made as to when an asset has arrived in an area and when an asset has left the area. Furthermore, this can be achieved without significantly reducing battery life, and this can be achieved without unnecessary radio frequency transmissions.

[0046] In addition to the aforementioned aspects and features of the invention, it should be noted that the invention further includes the various possible combinations of such aspects and features, including the combinations of such aspects and features with those aspects and features of the incorporated references from which priority is claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0047] Particular embodiments of the invention are to be understood according to the detailed descriptions that follow in conjunction with the attached figures, wherein:

[0048] FIG. 1 illustrates a plurality of nodes that form wireless ad hoc networks in accordance with common designation networking, wherein node N5 is sending out a wake-up broadcast to nodes having the “circle” common designation.

[0049] FIG. 2 illustrates the nodes of FIG. 1, wherein each of nodes N1 and N3 propagates the wake-up broadcast from node N5 and wherein each of nodes N1 and N3 engages in Bluetooth communications with node N5.

[0050] FIG. 3 illustrates the nodes of FIG. 1, wherein node N4 propagates the wake-up broadcast from node N5 and engages in Bluetooth communications with node N3, and wherein node N1 engages in Bluetooth communications with gateway G1.

[0051] FIG. 4 illustrates the nodes of FIG. 1 during a period of inactivity of transmissions between the nodes.

[0052] FIG. 5 illustrates the nodes of FIG. 1, wherein gateway G1 sends out a wake-up broadcast targeting node N1 and engages in Bluetooth communications with node N1.

[0053] FIG. 6 illustrates the nodes of FIG. 1, wherein node N1 sends out a wake-up broadcast targeting node N8 and engages in Bluetooth communications with node N8.

[0054] FIG. 7 illustrates a first exemplary data construct that is included in the wake-up broadcast in accordance with the present invention.

[0055] FIG. 8 illustrates a second exemplary data construct that is included in the wake-up broadcast in accordance with the present invention.

[0056] FIG. 9 illustrates a third exemplary data construct that is included in the wake-up broadcast in accordance with the present invention.

[0057] FIG. 10 illustrates an exemplary table of wake-up identifiers that may be maintained by node N2 in accordance with the present invention.

[0058] FIG. 11 illustrates an exemplary table of wake-up identifiers that may be maintained by gateway G1 in accordance with the present invention.

[0059] FIG. 12 is a first illustration representative of locations, states, and state transitions of radio frequency communication devices, at a first time, in accordance with one or more preferred embodiments of the present invention.

[0060] FIG. 13 is a second illustration representative of locations, states, and state transitions of radio frequency communication devices, at a second time subsequent to the first time, in accordance with one or more preferred embodiments of the present invention.

[0061] FIG. 14 is a third illustration representative of locations, states, and state transitions of radio frequency communication devices, at a third time subsequent to the second time, in accordance with one or more preferred embodiments of the present invention.

[0062] FIG. 15 is a fourth illustration representative of locations, states, and state transitions of radio frequency communication devices, at a fourth time subsequent to the third time, in accordance with one or more preferred embodiments of the present invention.

[0063] FIG. 16 is a fifth illustration representative of locations, states, and state transitions of radio frequency communication devices, at a fifth time subsequent to the fourth time, in accordance with one or more preferred embodiments of the present invention.

[0064] FIG. 17 is a sixth illustration representative of locations, states, and state transitions of radio frequency communication devices, at a sixth time subsequent to the fifth time, in accordance with one or more preferred embodiments of the present invention.

[0065] FIG. 18 is a seventh illustration representative of locations, states, and state transitions of radio frequency communication devices, at a seventh time subsequent to the sixth time, in accordance with one or more preferred embodiments of the present invention.

[0066] FIG. 19 is an eighth illustration representative of locations, states, and state transitions of radio frequency communication devices, at an eighth time subsequent to the seventh time, in accordance with one or more preferred embodiments of the present invention.

DETAILED DESCRIPTION

[0067] As a preliminary matter, it will readily be understood by one having ordinary skill in the relevant art (“Ordinary Artisan”) that the present invention has broad utility and application. Various embodiments are discussed for illustrative purposes in providing a full and enabling disclosure of the present invention. Moreover, many embodiments, such as adaptations, variations, modifications, and equivalent arrangements, will be implicitly disclosed by the descriptions of embodiments herein and fall within the scope of the present invention.

[0068] Accordingly, while the present invention is described herein in detail in relation to one or more embodiments, it is to be understood that this disclosure is illustrative and exemplary of the present invention, and is made merely for the purposes of providing a full and enabling disclosure of the present invention. The detailed disclosure herein of one or more embodiments is not intended, nor is to be construed, to limit the scope of patent protection afforded the present invention. It is not intended that the scope of patent protection afforded the present invention be defined by reading into any claim a limitation found herein that does not explicitly appear in the claim itself.

[0069] Thus, for example, any sequence(s) and/or temporal order of steps of various processes or methods that are described herein are illustrative and not restrictive. Accordingly, it should be understood that, although steps of various processes or methods may be shown and described as being
in a sequence or temporal order, the steps of any such processes or methods are not limited to being carried out in any particular sequence or order, absent an indication otherwise. Indeed, the steps in such processes or methods generally may be carried out in various different sequences and orders while still falling within the scope of the present invention. Accordingly, it is intended that the scope of patent protection afforded the present invention is to be defined by the appended claims rather than the description set forth herein.

[0070] Additionally, it is important to note that each term used herein refers to that which the Ordinary Artisan would understand such term to mean based on the contextual use of such term herein. To the extent that the meaning of a term used herein—as understood by the Ordinary Artisan based on the contextual use of such term—differs in any way from any particular dictionary definition of such term, it is intended that the meaning of the term as understood by the Ordinary Artisan should prevail.

[0071] Furthermore, it is important to note that, as used herein, “a” and “an” each generally denotes “at least one,” but does not exclude a plurality unless the contextual use dictates otherwise. Thus, reference to “a picnic basket having an apple” describes “a picnic basket having at least one apple” as well as “a picnic basket having apples.” In contrast, reference to “a picnic basket having a single apple” describes “a picnic basket having only one apple.”

[0072] When used herein to join a list of items, “or” denotes “at least one of the items,” but does not exclude a plurality of items of the list. Thus, reference to “a picnic basket having cheese or crackers” describes “a picnic basket having cheese without crackers,” “a picnic basket having crackers without cheese,” and “a picnic basket having both cheese and crackers.” Finally, when used herein to join a list of items, “and” denotes “all of the items of the list.” Thus, reference to “a picnic basket having cheese and crackers” describes “a picnic basket having cheese, wherein the picnic basket further has crackers,” as well as describes “a picnic basket having crackers, wherein the picnic basket further has cheese.”

[0073] Turning now to the drawings, FIGS. 1-6 each illustrate a plurality of nodes that form wireless ad hoc networks in accordance with common designation networking. The nodes in FIGS. 1-6 comprise nodes N1, N2, N3, N4, N5 and a gateway node G1. In each illustration, each node N1, N2, N3, N4 and N5 has a particular shape (a circle or a triangle), indicating a common designation that applies to that node, and the gateway node G1 has a square shape. In FIGS. 1-6, some of the shapes are shown with visual emphasis (i.e., with thicker lines, sometimes referred to herein as being shown in bold), indicating generally that the nodes represented by those shapes are active as set forth herein.

[0074] In accordance with the invention, a “node” generally refers to a wireless radio frequency data communication device that comprises a two-way communications component in the form of a transceiver that receives and transmits information wirelessly with one or more other nodes. The data communication device preferably includes a low-power radio frequency (“LPRF”) data communication device that communicates via data packets. The transmission of the data packets may utilize, for example, transmission control protocol (“TCP”). The two-way communications component of the data communication device also preferably is a standards-based radio (“SBR”) and comprises, for example, a Wi-Fi, WiMAX, CDMA, WCDMA, GSM, ZigBee, Ultra-Wideband, or Bluetooth radio. Indeed, in connection with the one or more preferred embodiments described below, the SBR preferably comprises a Bluetooth radio.

[0075] Generally, in receiving or transmitting information wirelessly between two nodes, a communications link is established between the SBRs of the two nodes and an electronic message then is transmitted via the communications link. Following transmission of the electronic message, the communications link is disconnected and the SBRs return to an inactive state for power conservation. Alternatively, the communications link established between the data communication devices of the two nodes may be maintained, if desired, in order to provide continuous communications between the two nodes without having to reestablish a communications link therebetween. Establishing a continuous communications link between two nodes without having to reestablish the communications link therebetween is particularly desirable, for instance, in transmitting real time audiovisual content, or in providing real time audiovisual communications between persons. Such person-to-person communications further may be “two-way” when each data communication device at each node includes dual radios. This is particularly true when Bluetooth radios are utilized, which do not include duplex capabilities. Thus, for example, maintaining continuous communications between two nodes each employing dual radios is particularly desirable if data packets for Voice-over-IP (“VoIP”) services are to be wirelessly transmitted between the two nodes. Once the continuous communications are no longer needed, the communications link is disconnected and the SBRs return to an inactive state for power conservation.

[0076] The data communication device of a node of the wireless network may be mobile or fixed at a particular location, and the data communication device may include an internal power supply source or utilize an external power supply source. The data communication device may include an interface for communicating with an associated sensor or other data acquisition device, which sensor may or may not form part of the node. The data communication device constituting the node also or alternatively may be attached to an asset that is to be monitored and/or tracked; alternatively, the data communication device constituting the node may be permanently affixed to a structure for monitoring and/or tracking assets that come within proximity thereto.

[0077] With respect to a “gateway” node, the gateway node preferably is configured for direct electronic communication with a network that is external to any ad hoc wireless network that may be formed by the nodes themselves. Communications between the gateway and the external network may be wireless or hard-wired and comprise, for example, a network interface card that accepts a CAT 5 cable for Ethernet communications; a cellular transceiver for communications via a cellular telephone network; a satellite transceiver for communications via a satellite network; or any combination thereof. The wired network itself may be a wide area network (“WAN”) and includes the Internet. Such a node is called a “gateway” node because it serves as a gateway for other nodes in communicating via the external network. A computer system further may be disposed in electronic communication with the same wired network, whereby the computer system and each node of the wireless
network may communicate with each other through the external network, such as the WAN, and the one or more gateways. Moreover, the computer system may include application software and a database, and the computer system may record and maintains information regarding the wireless network, nodes thereof, and/or data received therefrom. Such a computer system is sometimes referred to as a “server” and may be utilized to track and/or monitor asset that may be associated with the nodes. If the nodes are utilized simply for monitoring purposes irrespective of assets, such a server may be utilized for responding to conditions that are sensed by one or more of then nodes, including alerting appropriate third parties to a sensed condition.

[0078] In alternative embodiments, the server may be combined with a gateway node itself, which combination sometimes may be referred to as a “gateway controller” or “GC”. In such embodiments the gateway controller performs the aforementioned functions of the server. Also, the gateway controller preferably is still configured to communicate with an external network WAN, thereby providing an avenue for communicating from remote locations via the WAN with the gateway controller in order to access information that is recorded and maintained by the gateway controller.

[0079] In accordance with the invention, the nodes utilize common designation networking in combination with wake-up technologies. Common designation networking is perhaps best disclosed in the incorporated U.S. Pat. Nos. 6,745,027 and 7,221,668. When the nodes are associated with assets, common designation identifiers representing attributes or characteristics of the assets are typically used, which common designations often are referred to as “class” designations. Similarly, ad hoc networks formed based thereon are often referred to as “class-based” networks and communications in such networks are often referred to as “class-based” communications. In accordance with common designation networking, a node screens each transmission for a data identifier that represents a common designation of that node. The node does not process, route, or respond to an incoming transmission if the data identifier is not found. As will be appreciated, common designation networking greatly reduces redundancy when many nodes are within broadcast range of each other and greatly increase operating life of mobile nodes that depend on battery sources, as the nodes do not needlessly respond to all transmissions, filtering out and processing, routing, and/or responding to only those transmission bearing its common designation.

[0080] As further disclosed in the incorporated references, it will be appreciated that a node may have more than one common designation at any given time, and that a common designation may represent a subset or a superset of another common designation (sometimes referred to as class and subclass).

[0081] The wake-up technologies that are utilized in accordance with the invention are perhaps best disclosed in U.S. Pat. No. 7,209,771 and U.S. Patent Appl. Publication No. 2006/0287008. These two incorporated references disclose alternative approaches for the wake-up technologies that may be used.

[0082] Specifically, in incorporated U.S. Pat. No. 7,209,771, each node of the wireless ad hoc network includes—in connection with the SBR—a wake-up receiver that listens for a wake-up broadcast or signal, referred to generally as a “wake-up broadcast,” that includes a common designation of that node. Upon receiving such a wake-up broadcast, the wake-up receiver provides an electronic signal that activates the SBR, which resides in a dormant state (either off or in a reduced power standby mode) while the wake-up receiver is listening for an applicable broadcast. The wake-up receiver is a simplified receiver that draws much less current when listening for an applicable broadcast compared to the current that would be drawn by the SBR when listening for an applicable broadcast. Hence, significant power conservation and long battery life is achieved using such a wake-up receiver.

[0083] Furthermore, this wake-up receiver may screen only for a predetermined common designation, as disclosed in U.S. Patent Appl. Publication No. 2006/0287008. Alternatively, a more complicated stepped wake up of the SBR may be performed using the wake-up receiver, wherein the wake-up receiver first screens for one or more criteria before screening for the common designation in the wake-up broadcast. Such a stepped wake-up methodology is disclosed, for example, in the incorporated U.S. Patent Appl. Publication No. US 2006/0276161. Screening for criteria that is indicative of an actual wake-up broadcast being received can be beneficial when significant RF noise is present, whereby false indications of the receipt of a wake-up broadcast can be reduced.

[0084] In incorporated U.S. Patent Appl. Publication No. 2006/0287008, a wake-up transceiver is disclosed. The wake-up transceiver is similar to the aforementioned wake-up receiver, but further includes a transmitter by which a wake-up broadcast may be transmitted without necessarily having to activate the SBR. In the data communication devices of U.S. Pat. No. 7,209,771, the SBR sends a wake-up broadcast whereas, in U.S. Patent Appl. Publication No. 2006/0287008, the wake-up broadcast may be sent by the wake-up transceiver without having to activate the SBR. Avoiding booting up of the SBR has been found to result in significant power savings, and while the SBR has additional features and functionality not provided by the wake-up transceiver, such features and functionality are not required in transmitting a wake-up broadcast.

[0085] As used herein, “Wake-Up Component” is intended to mean either a wake-up receiver or a wake-up transceiver, as disclosed in these incorporated references, the data communication device of each node of FIG. 1 preferably includes such a Wake-Up Component.

[0086] Turning now to FIG. 1, node N5 is illustrated in bold, which represents that the SBR of node N5 is active. More particularly, node N5 is transmitting a wake-up broadcast (“WU”) to nodes in the broadcast range that have a “circle” common designation. The nodes within the broadcast range of node N5 are illustrated within the dashed circle of which node N5 is located at the center. Those nodes include nodes N1, N2, and N3, all of which include a dormant SBR as indicated by the lack of bold emphasis, and the wake-up broadcast is received by the Wake-Up Component of each of these nodes.

[0087] In accordance with an exemplary implementation, the wake-up broadcast includes the data construct with the hexadecimal value “00010001” as illustrated in FIG. 1. The pieces of information contained within the data construct in this exemplary implementation of the wake-up broadcast is illustrated in FIG. 7. As shown therein, the first sixteen bits (i.e., the first four digits of the hexadecimal value shown in
FIG. 1) represent the wake-up identifier portion of the wake-up broadcast. The next twelve bits (i.e., the next three digits of the hexadecimal value shown in FIG. 1) represent an identification of the node initiating the wake-up broadcast. Finally, the last four bits (i.e., the final digit of the hexadecimal value shown in FIG. 1) represent a rolling transmission or message count sent by the originating node. Accordingly, in interpreting the data construct with the hexadecimal value “00010051” illustrated in FIG. 1, the first four digits “0001” identify the common designation (in this case, defined as corresponding to the “circle” common designation); the next three digits “005” identify the node (in this case, defined as corresponding to N5) that is initiating the wake-up broadcast; and the last digit identifies a transmission or message count of “1”. For reference, various common designations, node IDs, and gateway IDs in an exemplary implementation are shown in the tables of FIGS. 10 and 11, and are exemplary in nature only.

As will now be apparent, the wake-up broadcast includes information in addition to that which is required merely to effect the wake-up of desired nodes. In particular, the wake-up broadcast includes networking information that may assist any node listening to the wake-up broadcast in facilitating networking communications itself.

Continuing with reference to FIG. 1, nodes N1 and N3 each have the common designation of “circle,” which is the common designation identified in the wake-up broadcast transmitted by Node N5. Thus, as shown in FIG. 2, the SBRs of these two nodes are awakened by their respective Wake-Up Components and (1) each propagates the wake-up broadcast received from node N5 by transmitting a wake-broadcast with the same data construct value 00010051; and (2) each engages in Bluetooth communications with Node N5 via the SBRs. The awakened state of the SBRs in nodes N1 and N3, as well as that of node N5, is represented by the bold emphasis of nodes N1, N3, and N5 in FIG. 2.

It furthermore will be appreciated that, while node N2 was within the range of the wake-up broadcasts of nodes N5 and N1, respectively, no common designation of node N2 was included in the data construct of either broadcast. Thus, node N2 did not “wake up” in response to either broadcast. On the other hand, node N2 has “heard” the wake-up broadcasts and has made note of the following networking information revealed by such wake-up broadcasts: (1) the presence of node N5 having the “circle” common designation within one hop from node N2; and (2) the presence of another node having the “circle” common designation within the broadcast range of node N2.

FIG. 3 represents the next sequence of events following those of FIG. 2. In this regard, FIG. 3 illustrates that node N4, which has the common designation of “circle”, responds to the wake-up broadcast propagated by node N3. As shown in FIG. 3, the SBR of node N4 is awakened by its Wake-Up Component and (1) node N4 propagates the wake-up broadcast received from node N3 by transmitting a wake-broadcast with the data construct 00010051; and (2) node N4 engages in Bluetooth communications with Node N3 via the SBRs. The awakened state of the SBR of node N4 is represented by the bold emphasis of node N4 in FIG. 3.

In addition, FIG. 3 illustrates that node N1 engages in Bluetooth communications with the gateway G1. In this regard, the gateway G1 preferably includes many, if not all, of the common designations that are shared by a plurality of nodes, including the “circle” and “triangle” common designations. This is illustrated in the table of FIG. 11, wherein the gateway has an “active” status for common designations identified by identifiers 1001-1006, including identifier 1001, assigned to the “circle” common designation, and 1005, assigned to the “triangle” common designation. The gateway G1 preferably does not include active status for common designations relating to the node attributes shown in FIG. 1, nor for the common designations representing the unique IDs of the nodes.

Accordingly, upon receiving the wake-up broadcast from node N1 shown in FIG. 2, the SBR of the gateway G1 was awakened by the Wake-Up Component of the node for engaging in Bluetooth communications with node N1 as shown in FIG. 3, and its awakened state is represented by the bold emphasis of the gateway G1 in FIG. 3. Furthermore, as shown, the wake-up broadcast is not propagated by the gateway.

It should further be appreciated that a node does not propagate the wake-up broadcast more than once. Each wake-up broadcast is screened based on the common designation, node ID, and transmission count from that node ID as identified in the data construct of the broadcast, and a wake-up broadcast having a matching data construct is not transmitted if there is an indication that such a wake-up broadcast has already been transmitted. Preferably, a list having a predetermined number of entries is maintained, with the oldest entries being discarded as new entries are added once the list has been populated.

FIG. 4 illustrates a period of inactivity of transmissions between the nodes. During this period, all of the SBRs of the nodes are dormant, as represented by the lack of any bold emphasis of any of the nodes. During this period, external communications may be occurring, for example with an external server based on the Bluetooth communications between node N1 and gateway G1 illustrated in FIG. 3.

FIG. 5 illustrates the next sequence of events in the present example. In FIG. 5, the SBR of the gateway G1 has been activated in response to a communication received from the external network for receipt by node N5. The message may be, for example, an acknowledgement, intended for node N5, of receipt of a message by a server.

In response, the gateway G1 transmits a wake-up broadcast that is targeted specifically for node N1. In this regard, the gateway G1 preferably knows the pathway to node N5 based at least upon the receipt of the message communicated via Bluetooth from node N5 to the gateway G1 by way of node N1. Such pathway identification preferably is accomplished using the deterministic and non-deterministic methodologies disclosed, for example, in the incorporated U.S. Patent Appl. Publication No. US 2007/0002792.

It furthermore will be appreciated that, although node N2 was within the range of the wake-up broadcast of gateway G1, no common designation of node N2 is included in the data construct of the broadcast (indeed, it was specifically targeted for node N1). Thus, node N2 did not “wake up” in response to the broadcast and, specifically, the SBR of node N2 was not activated. Nevertheless, node N2 “heard” the wake-up broadcast from gateway G1 and made note of the following networking information revealed by such wake-up broadcast: (1) the confirmed presence of gateway G1 (identified by node ID 0801) within a single hop
from node N2; and (2) the presence of node N1 (identified by the wake-up identifier "0101") presumed by gateway G1 to be within the broadcast range of node G1.

[0099] FIG. 6 illustrates node N1 transmission by node N1 of a wake-up broadcast targeting node N5 and the consequent Bluetooth communications engaged between node N1 and node N5. In particular, the node N1 transmits a wake-up broadcast that is intended specifically for node N5. Preferably, node N1 knows the pathway to node N8 based at least upon the prior communications with node N1 illustrated in connection with FIGS. 1-2. Again, such pathway identification preferably is accomplished using the deterministic and nondeterministic methodologies disclosed, for example, in the incorporated U.S. Patent Appl. Publication No. US 2007/00022792. Also shown in FIG. 6, once the SBR of node N5 is awaken, Bluetooth communications commence between the SBRs of node N5 and node N1.

[0100] Additionally, it should again be noted that although node N2 is within the range of the wake-up broadcast transmitted by node N1, no common designation of node N2 is included in the data construct of the broadcast (indeed, it was specifically targeted for node N5). Thus, node N2 did not “wake up” in response to the broadcast and, specifically, the SBR of node N2 was not activated. Nevertheless, node N2 “heard” the wake-up broadcast from node N1 and made note of the following networking information revealed by such wake-up broadcast: (1) the confirmed presence of node N1 (identified by node ID 0101) within a single hop from node N2; and (2) the presence of node N5 (identified by the wake-up identifier “0105”) presumed by node N1 to be within the broadcast range of node N1.

[0101] As referenced previously, FIG. 7 illustrates an exemplary data construct as found in the wake-up broadcasts (WU) of FIGS. 1-6. As described above, the eight-digit number shown in brackets by “WU” represents the hexadecimal equivalent of the 32-bit data construct format shown in FIG. 7. Moreover, while the data construct shown is 32 bits, it will be appreciated that any number of bits may be selected depending upon the number of possible wake-up identifiers, node IDs, and counts that are desired to be accommodated in implementing the present invention, and depending upon any other networking information that may be desired to be included in the wake-up broadcast.

[0102] For example, FIG. 8 illustrates another exemplary data construct that may be included in the wake-up broadcast (WU) in accordance with the present invention. In this example, the first 32 bits of the data construct represent the same pieces of information represented by the first 32 bits of the data construct of FIG. 7; however, the data construct includes an additional eight bits (for a total of 40 bits) wherein the additional last eight bits represent an encryption key. The encryption key may be utilized in symmetric or asymmetric encryption. In some contemplated embodiments, the encryption key is a public key. Preferably, each authorized data communication device is configured to use the encryption key to decrypt one or more pieces of the information contained in the data construct. The encrypted portions may include, for example, the wake-up identifier and/or the node ID. Nodes or other devices that do not have the ability to decrypt the information will not be able to contact the nodes or join the network. Moreover, hacking the network will be more difficult.

[0103] Instead of, or in addition to, using the encryption key to decrypt one or more portions of the wake-up broadcast, the encryption key may be utilized by the SBR to decrypt communications conducted via the SBR of the node. Provision of the encryption key via wake-up broadcasts for use in decrypting communications via SBRs represents an additional layer of network security, as SBRs may not necessarily be able to communicate with Wake-Up Components, especially when Wake-Up Transceivers are utilized. In such scenarios, two different avenues of communications are enabled with the encryption key being provided through one avenue for use in decrypting communications received via the second avenue.

[0104] It also should be appreciated that the encryption key could be used to encrypt communications by the node in addition to or rather than decrypting communications.

[0105] Still yet, FIG. 9 illustrates a third exemplary data construct that may be included in the wake-up broadcast (WU) in accordance with the present invention. In this example, the first 32 bits of the data construct represent the same pieces of information represented by the first 32 bits of the data construct of FIG. 7; however, the data construct includes an additional eight bits (for a total of 40 bits) wherein the additional last eight bits represents a payload of the wake-up broadcast in which a message or other data may be transmitted via the Wake-Up Components of the nodes. The payload data may include network information or may include information unrelated to the network itself. Such payload information may include, for example, application-specific data for an application executed by a destination node, an indication of the status of a sensor associated with a node (such as a seal or temperature sensor), and the like.

[0106] FIG. 10 illustrates an exemplary table of wake-up identifiers that may be maintained, for example, by node N2 in accordance with the present invention. As shown in FIG. 10, node N2 includes the following common designations: “0102” representing the unique node ID 102 of the node N2; “1000” representing a general wake-up identifier which all nodes preferably share; “1002” representing a “polygon” common designation; “1005” representing a “triangle” common designation; “1006” representing an “isosceles triangle” common designation; “3001” representing an attribute of the node, namely, that a gateway is available for communications to/from the node; and “3002” representing another attribute of the node, namely, that the node is located for communications directly with a gateway.

[0107] It will be appreciated that information noted by a node may be utilized to effect various functions. For example, as was described previously, node N2 “heard” the wake-up broadcast from gateway G1 and made note of certain networking information, including the confirmed presence of gateway G1 (identified by node ID 0801) within a single hop from node N2. If such information was previously unknown to node N2 (i.e., if the status for the wake-up identifier “3002” was previously set to inactive), then node N2 may, in response to the discovery of this information, change the status from inactive to active.

[0108] It will be understood that the foregoing wake-up identifiers are presented simply for illustration of the invention. One of countless alternative implementations is described in incorporated U.S. provisional patent application Ser. No. 60/890,900. Indeed, it is certainly contemplated that commercial implementations of the invention will include different identifiers more commercially meaningful and relevant than mere geometric shapes. For example, commercial implementations of the present invention...
t tion are particularly suited for use in asset tracking networks, asset monitoring networks, sensor data-acquisition networks, and combinations thereof. Such networks are disclosed, for example, in incorporated U.S. Pat. Nos. 6,934, 540 and 6,745,027, both of which relate to class-based networks for tracking and/or monitoring assets.

[0109] For example, in asset tracking/monitoring applications, such different wake-up identifiers could include classes corresponding to televisions, appliances, and consumer electronics; with supersets including Sony, Whirlpool, and Phillips; and with subsets including plasma televisions, dishwashers, and electric razors. In sensor network implementations, such different wake-up identifiers could include common designations corresponding to each different type of sensor; each different location or area of the sensors; and each manufacturer of the sensors. If the sensor networks are deployed for or on behalf of third parties as part of commercial services offered, then wake-up identifiers further could include common designations corresponding to each different customer or each different location of the customer where such services are utilized.

[0110] FIG. 11 illustrates an exemplary table of wake-up identifiers that may be maintained by gateway G1 in accordance with the present invention. As shown in FIG. 11, gateway G1 includes the following common designations: “0801” representing the unique gateway ID 101 of the gateway G1; “1000” representing a general wake-up identifier which all nodes (including gateway nodes) preferably share; “1001” representing a “circle” common designation; “1002” representing a “rectangle” common designation; “1003” representing a “polygon” common designation; “1004” representing a “square” common designation; “1005” representing a “triangle” common designation; and “1006” representing an “isosceles triangle” common designation.

[0111] As will now be appreciated from the foregoing description, nodes in common designation networks that utilize Wake-Up Components have great listening capacity. By simply listening with its Wake-Up Component and recording networking information gleaned from wake-up broadcasts, a node can greatly improve its performance as well as the overall network performance. Indeed, many advantages can be gained by simply facilitating network communications. By providing networking information in the wake-up broadcasts, nodes are able to more efficiently make network connections and communicate with desired nodes and/or an external network. For example, just by listening and noting network information in a wake-up broadcast, a node can determine that it is only a single hop to a gateway without having to do initiate its own pathway query. The time previously required in certain situations for a node or gateway to communicate with a data communications device that is within range thus can be reduced. The opportunities for collision, which could delay network communications, is also reduced. Battery power also is conserved by reducing the number of times that an SBR needs to be activated from its dormant state. In contrast to these benefits, the small amount of networking data provided in the wake-up broadcasts does not overburden the simple Wake-Up Components, and thus the invention provides important advantages with little cost.

[0112] Turning now to the drawings, FIG. 12 is representative of locations, states, and state transitions of radio frequency communication devices shown at a first time in accordance with one or more preferred embodiments of the present invention.

[0113] In this regard, nine radio frequency communication devices 10 labeled “RSI R1,” through “RSI R9,” are shown in FIG. 12. Each radio frequency communication device 10 preferably comprises a movable remote sensor interface or “RSI” that includes its own internal power source, such as a battery. Each RSI preferably is active or at least semi-active, and each RSI preferably is disposed in electronic communication with one or more sensors through one or more interfaces of the RSI for receiving sensor signals including, for example, sensor-acquired data. Such sensors may comprise, for example, temperature sensors, motion sensors, accelerometer sensors, and GPS receivers.

[0114] The nine communication devices 10 are distributed among different physical areas (m being some integer greater than 1). These areas are represented by areas 12, 14, 16, 18 illustrated in FIG. 12. Each area may be at the same location as another area or at a different location as another area. For instance, area 12 may represent a boat dock (area) at a port of entry (location) and area 14 may represent a truck loading dock (area) at the same port of entry (location). Alternatively, area 12 may represent a warehouse (area) in Charleston, S.C. (location) and area 14 may represent a warehouse (area) in San Diego, Calif. (location). Moreover, area 16 may represent the cargo area (area) of a transport vehicle (location) in route between area 12 in Charleston and area 14 in San Diego, and the location thus need not be stationary. In this example, the location is dynamic and changes as the transport vehicle moves between Charleston and San Diego.

[0115] Furthermore, in accordance with one or more aspects of the present invention, at least one of the sensors associated with an RSI is utilized to indicate the likely removal of the RSI from an area, as discussed in greater detail below.

[0116] Each of them areas includes at least one gateway and, accordingly, there are at least m gateways represented in FIG. 12. These gateways are represented by gateways 20, 22, 24, 26. In this regard, gateway 20 is illustrated as being within area 12 and is labeled “Gateway G1”; gateway 22 is illustrated as being within area 14 and is labeled “Gateway G1”; gateway 24 is illustrated as being within area 16 and is labeled “Gateway G1”; and gateway 26 is illustrated as being within area 18 and is labeled “Gateway G1.”

[0117] Each gateway 20, 22, 24, 26 preferably is disposed in electronic communication with one or more servers labeled, respectively, “Server S1,” “Server S2,” and “Server Sn,” wherein n is some integer greater than 1. The servers are represented by server 28, 30, 32 and may be remotely located to each other. The servers 28, 30, 32 also may be remotely located to the gateways 20, 22, 24, 26. The electronic communication between the servers and the gateways 28, 30, 32 may be accomplished, for example, by way of cellular communications, satellite communications, and/or Internet communications.

[0118] Preferably, the communication devices 10 are associated with assets, and the servers 28, 30, 32 collectively include the programs and databases of one or more asset tracking systems for tracking and/or monitoring of the assets with which the communication devices 10 are associated.
The gateways and the communication devices further preferably form common designation networks and, more preferably, class-based networks.

[0119] With further reference to FIG. 12, each gateway 20, 22, 24, 26 is shown at a first time \( t_1 \) in FIG. 12 as making a respective radio frequency transmission that preferably awakens each communication device 10 from a sleep or standby mode, as appropriate. In this regard, this radio frequency transmission preferably comprises a wake up broadcast that includes a common designation comprising a class designation. If the class designation matches a class designation maintained in a table of class designations of a respective communication device 10, then that communication device 10 awakens and makes a radio frequency transmission in response. For brevity, a radio frequency transmission that is a wake up broadcast and that includes a class designation is sometimes referred to herein as a “Class-Present Wakeup Broadcast” and is simply labeled “Present” in the drawings. As will be appreciated, the Class-Present Wakeup Broadcasts represent a particular type of—and if a subset of—Present Broadcasts.

[0120] Additionally, the transmission in response to the Class-Present Wakeup Broadcast by the respective communication device 10 preferably includes an identification of the respective communication device 10. Such an identification may uniquely identify the respective communication device 10 or radio of the communication device 10. Alternatively, the identification may uniquely identify one or more assets with which the communication device 10 is associated in an asset tracking system, especially when the communication device is a wireless reader tag (WRT) or similar device. Alternatively, the identification may serve to distinguish the respective communication device 10 from one or more other communication devices 10 without uniquely identifying the respective communication device 10 from all other communication devices 10.

[0121] The Class-Present Wakeup Broadcast made by each gateway 20, 22, 24, 26 is received by each communication device within the respective area of the gateway, and each communication device 10 is shown as responding to the Class-Present Wakeup Broadcast, wherein each response is represented by a lightning bolt.

[0122] As will be appreciated, an RSI further can retransmit the Class-Present Wakeup Broadcast to other RSIs that fall outside of the gateway range, thereby expanding the effective range of communications with the gateway. Communications between a gateway and one or more RSIs outside of the gateway’s range, via one or more RSIs within range, is disclosed in one or more of the incorporated references but, for clarity, is not shown in the present drawings. Communications between an RSI and a gateway further may be through other RSIs even when all RSIs are within range of the gateway, as disclosed, for example, in many of the incorporated references such as U.S. Pat. Nos. 6,745,027 and 6,934,540.

[0123] As will be appreciated from the following detailed description, and in accordance with preferred embodiments of the invention, the fact that each of the nine communication devices 10 responds to the Class-Present Wakeup Broadcast indicates that none of the nine communication devices 10 likely were present in the areas 12,14,16,18 as shown in FIG. 12 at the time of a Class-Present Wakeup Broadcast first preceding that at time \( t_1 \). Furthermore, each communication device 10 responds to a Class-Present Wakeup Broadcast, as appropriate, regardless of the number of times that the communication device 10 has previously responded. Whether a communication device 10 responds preferably is not a function of the number of times that communication device 10 has responded in the past.

[0124] The Class-Present Wakeup Broadcast may be performed by each respective gateway “on demand” upon receipt of an instruction to such effect from one of the servers 28, 30, 32. Alternatively, each gateway may be configured to make the Class-Present Wakeup Broadcast in accordance with a predetermined schedule, such as at regular intervals of time. If timers are utilized, then the timers of the gateways determine the resolution within which a communication device is identified as having arrived at a particular area. Still yet, a particular gateway may be triggered to make a Class-Present Wakeup Broadcast by one or more sensors, such as motion, optical, or infrared sensors. Indeed, while gateways are concurrently shown in the drawings as making Class-Present Wakeup Broadcasts, a gateway nevertheless may make a Class-Present Wakeup Broadcast independent of one or more other gateways.

[0125] The transmissions made in response to the Class-Present Wakeup Broadcast and, in particular, the identification included in each response, is communicated through each gateway to an appropriate one or more of the servers 28, 30, 32 that is tasked with keeping track of the location of each communication device 10. Based upon the particular gateway from which a respective identification is received, the server may then determine that the respective communication device 10 corresponding to that identification is within the area of that particular gateway.

[0126] Accordingly, from the responses to the Class-Present Wakeup Broadcasts shown in FIG. 12, the appropriate server determines that: RSIs \( R_1 \), \( R_2 \), and \( R_3 \) are within the area of Gateway \( G_1 \); RSIs \( R_5 \) and \( R_6 \) are within the area of Gateway \( G_2 \); RSIs \( R_6 \), \( R_7 \), and \( R_8 \) are within the area of Gateway \( G_3 \); and RSIs \( R_9 \) is within the area of Gateway \( G_4 \). Preferably, the server records and maintains such location information for each of the communication devices 10.

[0127] Thereafter, each gateway 20, 22, 24, 26 is shown at a second time subsequent to the first time in FIG. 13 as making a respective subsequent Class-Present Wakeup Broadcast. Again, the Class-Present Wakeup Broadcast made by each gateway 20, 22, 24, 26 is received by each communication device within the respective area of the gateway; however, none of the communication devices 10 is shown as responding to the Class-Present Wakeup Broadcast. In accordance with preferred embodiments of the invention, none of the communication devices 10 respond to the Class-Present Wakeup Broadcast because each has already responded to a Class-Present Wakeup Broadcast at time \( t_1 \), and each has yet to move from the respective area in which it was located since that time.

[0128] As will be appreciated, the server tasked with keeping track of the location of each communication device 10 receive no identification from any communication device 10 via the gateways 20, 22, 24, 26 and, based thereon, does not update any location information for any of the communication devices 10. Having received no identifications in response to the Class-Present Wakeup Broadcasts, the server assumes that none of the communication devices 10 have been moved from their respective areas as recorded by the server.
At a third time subsequent to the second time, as shown in FIG. 14, communication device 10 labeled as RSI R₂ is moved from the area 12 of the gateway 20 (Gateway G₁). The RSI R₂ preferably is disposed in electrical communication with a motion sensor through an interface thereof and, upon being moved, the RSI R₂ preferably receives sensor-acquired information from the motion sensor that indicates the movement of the RSI R₂. Such electrical communication may be wired or wireless, and the sensor may be internal or external to a housing of the communication device. The RSI R₂ preferably is configured, upon receipt of such sensor-acquired information through the interface, to make a radio frequency transmission including an identification thereof to an appropriate server via the gateway 20. The server preferably is the server that records and maintains the location information for each of the communication devices 10 and, upon receipt of the communication from RSI R₂, the server preferably records information pertaining to such communication. In particular, the server preferably records information indicating movement of RSI R₂ and the time t₃ of such movement. The movement is presumed to indicate the likely removal of the RSI R₂ from the area. Other sensors, or a combination of sensors, further can be used to indicate such likely removal. For example, the combined readings from both a motion sensor and a temperature sensor could be used to indicate likely removal of the communication device from a particular area. Alternatively, temperature rather than motion could be used as an indicator that the communication device likely has moved from a controlled environment of a particular area.

At a fourth time subsequent to the third time, as shown in FIG. 15, communication device 10 labeled as RSI R₄ moved from the area 14 of the gateway 22 (Gateway G₂). The RSI R₄ preferably is disposed in electrical communication with a motion sensor through an interface thereof and, upon being moved, the RSI R₄ preferably receives sensor-acquired information from the motion sensor that indicates the movement of the RSI R₄. Such electrical communication may be wired or wireless, and the sensor may be internal or external to the RSI. The RSI R₄ preferably is configured, upon receipt of such sensor-acquired information through the interface, to make a radio frequency transmission including an identification thereof to an appropriate server via the gateway 22. The server preferably is the server that records and maintains the location information for each of the communication devices 10 and, upon receipt of the communication from RSI R₄, the server preferably records information pertaining to such communication. In particular, the server preferably records information indicating movement of RSI R₄ and the time t₄ of such movement.

At a fifth time subsequent to the fourth time, as shown in FIG. 16, the gateways 20, 22, 24, 26 again make Class-Present Wakeup Broadcasts. As will be appreciated, none of the communication devices 10 respond to the Class-Present Wakeup Broadcast that have not moved since the preceding Class-Present Wakeup Broadcast at time t₄; such communications generally would be unnecessary and would thus needlessly drain power sources of the communication devices 10. On the other hand, RSI R₄ which was moved at time t₄ has since moved into the area 14 of gateway 22 (Gateway G₂) by time t₅ and, in response to the Class-Present Wakeup Broadcast received from gateway 22, the RSI R₄ does make a responsive transmission that includes an identification thereof. As a result of this responsive transmission, the server tracking the location information of RSI R₄ updates the location information to indicate that RSI R₄ now is in area 16 as of time t₅. RSI R₄, on the other hand, did not respond to the Class-Present Wakeup Broadcasts and, as such, its absence from areas 12, 14, 16, 18 is identified. It further deemed that it was moved from area 14 at time t₆.

At a sixth time subsequent to the fifth time, as shown in FIG. 17, communication device 10 labeled as RSI R₆ is moved from the area 18 of the gateway 26 (Gateway G₃). The RSI R₆ preferably is disposed in electrical communication with a motion sensor through an interface thereof and, upon being moved, the RSI R₆ preferably receives sensor-acquired information from the motion sensor that indicates the movement of the RSI R₆. Such electrical communication may be wired or wireless, and the sensor may be internal or external to the RSI. The RSI R₆ preferably is configured, upon receipt of such sensor-acquired information through the interface, to make a radio frequency transmission including an identification thereof to an appropriate server via the gateway 26. The server preferably is the server that records and maintains the location information for each of the communication devices 10 and, upon receipt of the communication from RSI R₆, the server preferably records information pertaining to such communication. In particular, the server preferably records information indicating movement of RSI R₆ and the time t₆ of such movement.

At a seventh time subsequent to the sixth time, as shown in FIG. 18, the gateways 20, 22, 24, 26 again make Class-Present Wakeup Broadcasts. As will be appreciated, none of the communication devices 10 respond to the Class-Present Wakeup Broadcast that have not moved since the preceding Class-Present Wakeup Broadcast at time t₆; such communications generally would be unnecessary and would thus needlessly drain power sources of the communication devices 10. On the other hand, RSI R₆ which was moved at time t₆ has since moved into the area 14 of gateway 22 (Gateway G₂) by time t₇ and, in response to the Class-Present Wakeup Broadcast received from gateway 22, the RSI R₆ does make a responsive transmission that includes an identification thereof. As a result of this responsive transmission, the server tracking the location information of RSI R₆ updates the location information to indicate that RSI R₆ now is in area 14 as of time t₇.

Additionally, RSI R₄ which was moved at time t₄ has moved into the area 1 of gateway 20 (Gateway G₁) by time t₈ and, in response to the Class-Present Wakeup Broadcast received from gateway 20, the RSI R₄ does make a responsive transmission that includes an identification thereof. As a result of this responsive transmission, the server tracking the location information of RSI R₄ updates the location information to indicate that RSI R₄ now is in area 10 as of time t₈.

Thereafter, each gateway 20, 22, 24, 26 is shown in FIG. 19 making a respective subsequent Class-Present Wakeup Broadcast at an eighth time subsequent to the seventh. Again, the Class-Present Wakeup Broadcast made by each gateway 20, 22, 24, 26 is received by each communication device within the respective area of the gateway; however, none of the communication devices 10 is shown as responding to the Class-Present Wakeup Broadcast. In accordance with preferred embodiments of the invention, none of the communication devices 10 responds to the
Class-Present Wakeup Broadcast because each communication device 10 has already responded as late as time t₁ to a previous Class-Present Wakeup Broadcast and has yet to be moved since such time of response. Accordingly, no responsive transmissions are needlessly made by any of the communication devices 10.

[0136] Each of the communication devices 10 shown in FIGS. 12-19 preferably operates in at least two states. In a first state, a communication device 10 responds to receipt of a Class-Present Wakeup Broadcast from a gateway 20, 22, 24, 26 by making a transmission that includes an identification thereof. After this responsive transmission, the communication device 10 preferably enters a second state in which it does not respond to Class-Present Wakeup Broadcasts. The communication device 10 preferably remains in this second state until sensor-acquired information received through an interface thereof indicates that a predefined condition has occurred, such as movement of the communication device 10. Upon the occurrence of the predefined condition, the communication device 10 preferably makes a transmission that includes an indication of the occurrence of the predefined condition as well as an identification of the communication device 10. Upon making the transmission, the communication device 10 preferably enters the first state.

[0137] During each of the two states, the communication device 10 still wakes up and/or responds to any transmission that includes a common designation (such as a class designation) that matches a common designation of the communication device 10. Preferably, each communication device 10 keeps a table of applicable common designations to which it belongs. In this respect, a common designation preferably is used to represent the Class-Present Wakeup Broadcast and this common designation is either enabled or disabled in the table as maintained by the communication device 10 depending upon whether the communication device 10 should respond to a Class-Present Wakeup Broadcast that is next received.

[0138] Specifically, after the communication device 10 has made a responsive transmission to a Class-Present Wakeup Broadcast, the communication device 10 preferably enables a motion sensor, disables the “present” common designation in its table, and waits to be awoken upon an indication of movement from the motion sensor. Furthermore, the enablement of the motion sensor and the disablement of the “present” common designation in its table may be automatically performed by the communication device itself following its response to the Class-Based Wakeup Broadcast, or may be performed by the communication device in direct response to instructions received from a server following the identification of the presence of the RSI to the server.

[0139] Thereafter, once the communication device 10 moves, the communication device 10 is awoken by the motion sensor and communicates, via a respective gateway, an indication of such movement to the appropriate server. The communication device 10 also then disable the motion sensor and enables the “present” common designation for waking up the communication device 10 for response to the next Class-Present Wakeup Broadcast.

[0140] This algorithm for entering the two different states enables the communication device 10 to “check in” when it arrives within an area of a gateway, to remain off or in standby after it has “checked in” in order to conserve internal power and avoid spurious transmissions; and to alert an appropriate server if the communication device 10 is moved.

[0141] A benefit of at least one embodiment of the invention is the avoidance of unnecessary and/or undesired radio frequency transmissions during air shipments in a cargo area of an airplane. Specifically, when communication devices 10, preferably associated with assets being tracked and/or monitored, are loaded into the cargo area of an airplane, a Class-Present Wakeup Broadcast is made in order to identify the communication devices present for taking inventory of the cargo. An instruction then is broadcast causing the communication devices to enter the second state, in which the motion sensors then are disabled. A Class-Present Wakeup Broadcast is not made until after the airplane has arrived at its intended location.

[0142] Since the motion sensor is turned off when the “present” common designation is enabled, the communication device 10 will not continuously try to report back to the server while it is in motion in the airplane. During movement, such as that associated with air transportation, the communication device 10 thus remains in a power conservation mode until it comes within range of the next gateway and receives a Class-Present Wakeup Broadcast.

[0143] As will be appreciated from the foregoing description, the movement of a communication device 10 is tightly monitored by one or more servers, since any communication device 10 within range of a gateway 20, 22, 24, 26 reports when a predefined condition, e.g., movement, has occurred that indicates that it has been likely moved out of the respective area in which it was residing. Moreover, unnecessary transmissions in response to Class-Present Wakeup Broadcasts are avoided when a communication device 10 has not moved out of the respective area in which it resides.

[0144] In alternatives to the arrangements represented in FIGS. 12-19, the n servers can be consolidated into a single server; and/or one or more servers can be combined with one or more gateways. Such changes may reduce networking costs, delays, and overhead associated with asset tracking systems, but the flexibility, capabilities, and/or robustness of the systems likewise may be reduced.

[0145] One or more aspects of the invention further may be utilized with a single area for maintaining visibility of assets within the single area without regard to visibility of the assets in other areas, if desired.

[0146] Another benefit of at least one embodiment of the invention is the ability to synchronize reporting from a plurality of radio frequency communication devices to a server. In this respect, radio frequency communication devices preferably communicate data that otherwise is being stored to a server concurrently when responding to a Present Broadcast. The concurrent communication of the data with a Present Response obviates the need for the communications device to wake-up at a later time for the specific purposes of communicating the stored data. As such, a group of communication devices can be manipulated, for example, into the first state such that each responds to a Present Broadcast by communicating not only a Present Response, but the stored data at each respective communication device. Such manipulation into the first state can occur, for example, by creating a predetermined condition (e.g., change in temperature, change in location, or movement), resulting in sensor signals causing the communication devices to enter
the first state from the second state; and/or by broadcasting an instruction to the communication devices to enter the first state.

[0147] In view of the foregoing, one or more benefits of one or more aspects of the present invention include: an increased battery life; the ability to transport assets by land, sea, or air without unnecessary or unwanted transmissions from the radios associated with the assets; the ability to still communicate “on demand” with a particular asset based on a common designation or class; the ability to determine assets newly arrived within an area “on demand” independent of any broadcasts at regular time intervals; the ability of an asset to “hide” from unauthorized persons by not needlessly identifying its presence in response to a general radio frequency broadcast; and the ability to determine when an asset is moved from an area once the asset has been identified as having arrived within the area.

[0148] Based on the foregoing description, it will be readily understood by those persons skilled in the art that the present invention is susceptible of broad utility and application. Many embodiments and adaptations of the present invention other than those specifically described herein, as well as many variations, modifications, and equivalent arrangements, will be apparent from or reasonably suggested by the present invention and the foregoing descriptions thereof, without departing from the substance or scope of the present invention. Accordingly, while the present invention has been described herein in detail in relation to one or more preferred embodiments, it is to be understood that this disclosure is only illustrative and exemplary of the present invention and is made merely for the purpose of providing a full and enabling disclosure of the invention. The foregoing disclosure is not intended to be construed to limit the present invention or otherwise exclude any such other embodiments, adaptations, variations, modifications or equivalent arrangements, the present invention being limited only by the claims appended hereto and the equivalents thereof.

1. A wireless communication device, comprising:
   - a radio receiver configured to receive a radio transmission as data representative of a general inquiry as to the presence of wireless communication devices;
   - a radio transmitter configured to respond to the received radio transmission with an identifier associated with the wireless communication device, the wireless communication device configured to enter a low-power state in which the wireless communication device does not respond to additional radio transmissions that include the data representative of the general inquiry as to the presence of wireless communication devices; and
   - an interface for receiving one or more signals from a sensor, the interface configured to:
     - receive a sensor signal based on sensor-acquired data that is indicative of a predetermined condition; and
     - in response to the reception of the sensor signal, exit the low-power state and transmit an additional radio transmission that includes the identifier associated with the wireless communication device.

2. The wireless communication device of claim 1, comprising a timer, and wherein the wireless communication device is configured to use the timer as an indication of when to transmit at periodic intervals.

3. The wireless communication device of claim 1, wherein the sensor is a motion sensor.

4. The wireless communication device of claim 1, wherein the sensor is a temperature sensor.

5. The wireless communication device of claim 1, wherein the sensor is a GPS receiver.

6. The wireless communication device of claim 5, wherein the predetermined condition comprises movement of the wireless communication device as determined by the GPS receiver.

7. The wireless communication device of claim 6, wherein the determined movement of the wireless communication device is based on sensor-acquired data exceeding a threshold based on a comparison of the sensor-acquired data to a geofence.

8. The wireless communication device of claim 1, wherein the predetermined condition is one or more of: a change in temperature, a change in location, or movement of the wireless communication device.

9. The wireless communication device of claim 1, further comprising a housing and wherein the sensor is internal to the housing of the wireless communication device.

10. The wireless communication device of claim 1, further comprising a housing and wherein the sensor is external to the housing of the wireless communication device.

11. The wireless communication device of claim 1, wherein the wireless communication device comprises one or more additional interfaces configured to receive additional signals from one or more additional sensors.

12. The wireless communication device of claim 11, wherein the predetermined condition is based on the additional signals from multiple sensors of the one or more additional sensors.

13. A wireless sensor network system comprising:
   - a gateway node configured to transmit a radio packet that includes data representative of a general inquiry as to the presence of wireless network nodes;
   - a wireless network node configured to:
     - receive the radio packet that includes the data representative of the general inquiry as to the presence of the wireless network nodes;
     - respond to the received packet by transmission of a response radio packet that includes an identifier associated with the wireless network node;
     - enter a low-power state in which the wireless network node does not respond to additional radio packets that include the data representative of the general inquiry as to the presence of wireless network nodes;
     - receive a sensor signal, via an interface, based on sensor-acquired data that is indicative of a predetermined condition; and
     - in response to the reception of the sensor signal, exit the low-power state and transmit an additional radio packet that includes the identifier associated with the wireless network node.

14. The wireless sensor network system of claim 13, wherein the gateway node is configured to:
   - receive the response radio packet; and
   - receive the additional radio packet.

15. The wireless sensor network system of claim 13, wherein the sensor signal is received from a sensor configured as one of: a motion sensor, a temperature sensor, or a GPS receiver.

16. The wireless sensor network system of claim 13, wherein the wireless network node comprises a timer, and
wherein the wireless network node is configured to use the timer as an indication of when to transmit at periodic intervals.

17. The wireless sensor network system of claim 13, wherein the predetermined condition is one or more of: a change in temperature, a change in location, or movement of the wireless network node.

18. A method of reporting the presence of a communication device in a wireless network, the method comprising:

- receiving, by the communication device while the communication device is in a first state, a radio transmission that includes data representative of a general inquiry as to the presence of communication devices;
- responding to the received radio transmission by generating a radio transmission that includes an identifier associated with the communication device;
- entering a second state in which the communication device does not respond to additional radio transmissions that include the data representative of the general inquiry as to the presence of communication devices;
- receiving, via an interface, a sensor signal based on sensor-acquired data that is indicative of a predetermined condition;
- returning to the first state in response to the receiving the sensor signal; and
- transmitting an additional radio transmission that includes the identifier associated with the wireless communication device.

19. The method of claim 18, wherein the sensor signal is received from a sensor configured as one of: a motion sensor, a temperature sensor, or a GPS receiver.

20. The method of claim 18, wherein the predetermined condition is one or more of: a change in temperature, a change in location, or movement of the communication device.