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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
26 August 2010 (26.08.2010)

PCT

(10) International Publication Number
WO 2010/095923 A2

(51) International Patent Classification:
H04W 84/18 (2009.01) *H04W 88/18* (2009.01)

(21) International Application Number:
PCT/MY2010/000024

(22) International Filing Date:
18 February 2010 (18.02.2010)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
PI20090630 18 February 2009 (18.02.2009) MY

(71) Applicant *(for all designated States except US)*: **MIMOS BERHAD** [MY/MY]; Technology Park of Malaysia, Bukit Jalil, 57000 Kuala Lumpur (MY).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **WAN KAMAL, Wan Hasmi** [MY/MY]; Mimos Berhad, Technology Park of Malaysia, Bukit JaIiI, 57000 Kuala Lumpur (MY). **RIZAL, Ahmad** [MY/MY]; Mimos Berhad, Technology Park of Malaysia, Bukit JaIiI, 57000 Kuala Lumpur (MY). **ABDUL HAMID, Abdul Rahim** [MY/MY]; Mimos Berhad, Technology Park of Malaysia, Bukit JaIiI, 57000 Kuala Lumpur (MY). **NIZAR, Ahmad** [MY/MY]; Mimos Berhad, Technology Park of Malaysia, Bukit JaIiI, 57000 Kuala Lumpur (MY). **HISHAM, Badrul** [MY/MY]; Mimos Berhad, Technology Park of Malaysia, Bukit JaIiI, 57000 Kuala Lumpur (MY). **ASBARI, Muhammad** [MY/MY]; Mimos Berhad, Technology Park of Malaysia, Bukit JaIiI, 57000 Kuala Lumpur (MY). **MOHD NAJMI, Mohd, Arif, Safaruddin** [MY/MY]; Mimos Berhad, Technology Park of Malaysia, Bukit JaIiI, 57000 Kuala Lumpur (MY).

(74) Agent: **MOHAN K**; Adastra Intellectual Property SDN BHD, A-28-10, Menara UOA Bangsar, No.5, Jalan Bangsar Utama 1, 59000 Kuala Lumpur (MY).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

(54) **Title**: WIRELESS SENSOR NETWORK SYSTEM

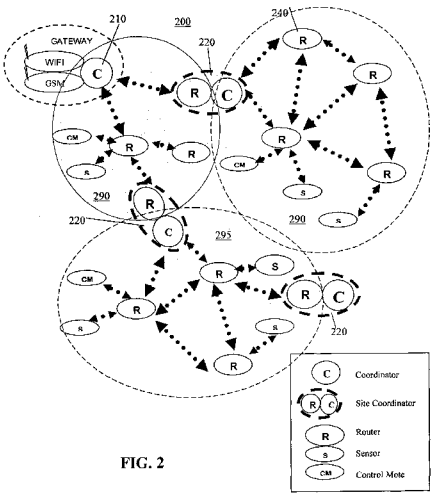

FIG. 2

(57) **Abstract**: The present invention provides a wireless sensor network (WSN) (200) having a main coordinator (210), a site coordinator (400) and a method therefor. The WSN (100) comprises a plurality of site coordinators (220), each forms a site WSN (290) and functioned by its own, and collectively, the plurality of site WSNs (290) forms the WSN (200). Each site coordinator (220) is operable to collect and store data collected/acquired from the respective site WSN (290) and to route out the collected/acquired data to the main coordinator (210) as appropriately.

WO 2010/095923 A2

Wireless Sensor Network System

Field of Invention

The present invention relates to a wireless sensor network. More particularly, the present invention relates to a wireless sensor network for precision agriculture field deployment.

Background of the Invention

Wireless sensor network (WSN) has been used to be deployed in a field of interest to cooperatively monitor physical or environmental conditions with sensors integrated with wireless transmission technologies. A WSN usually includes end (sensor) devices, router devices and a coordinator.

The advantage behind WSN technology is that it has a multi-hop or mesh network capabilities to send and route messages and data from source to final destination. and with this ability, the wireless range problem is not an issue. However, there is certain limitation in implementing the wireless sensor network for high number of sensors due to low and limited battery power and also limited memory space inside the controller unit.

ZigBee network, for example, was originated for home automation application. In such application, power supply is generally not a concern for routers and end devices as direct power supply is easily accessible. When WSN is deployed in a field where the power supply is not easily accessible, the network may need to rely on portable power source, such as

batteries, which has limited power supply over time. Further, a WSN with single coordinator is not meant for large scale network due to lack of memory space and resources.

FIG. 1 illustrates a typical WSN known in the art. The WSN includes a plurality of routers that collect data from the sensor motes and direct to the coordinator via an ad-hoc network. The coordinator may be a gateway that further directs the sensed information to other network via any wireless communication means, such as Wi-Fi and GSM. As mentioned, such network contains limited number of sensors, thereby the field coverage is also limited.

US patent publication no. US2006/0268745 discloses a clustering method of WSN to minimize energy consumption. It uses same sensor motes as site coordinator to handle the cluster network.

US patent publication no. US2008/0037569 discloses a method and apparatus for wireless communication in a mesh network using soft proxies. It suggests a network expansion for large area deployment. The apparatus too uses same sensor motes for expansion with soft algorithm as proxy device.

Summary of the Invention

In one aspect of the present invention, there is provided a wireless sensor network (WSN) having a main coordinator. The WSN comprises a plurality of site coordinators, each forms a site WSN and functioned by its own, and collectively, the plurality of site WSNs form the WSN. Each site coordinator is operable to collect and store data collected/acquired from the

respective site WSN and to rout out the collected/acquired data to the main coordinator as appropriately.

In one embodiment, operationally, each site WSN (290) works independently, where one of the site WSNs is operable in a sleep mode while other site WSNs are operable in an operating mode. The site coordinator may be integrated with a routing unit.

In another embodiment, the WSN is expandable by including one or more site WSN, each manages by a site coordinator.

In accordance with another aspect, there is provided a site coordinator of a site WSN (290). The site coordinator comprises a data storage unit; a coordinator microcontroller (MCU) for coordinating data collected/acquired within the site WSN; and a routing MCU for routing the collected/acquired data collectively to other site WSN. the data collected/acquired through the coordinator MCU is stored in the data storage unit, and the collected/acquired data are routed to other WSN as appropriately through the routing MCU.

In one embodiment, the coordinating MCU, the routing MCU and the data storage unit are interconnected through I2C connection. Operationally, the routing MCU may be initialized as master when the coordinating MCU is initialized as slave.

In another embodiment, the coordinating MCU is connected to the routing MCU via a bidirectional data line and a bidirectional clock line.

In a further aspect of the present invention, there is provided a method of collecting/acquiring data from a WSN. The method comprises initializing a routing MCU as master; initializing a coordinating MCU as slave; storing the collected/acquired data into a data storage unit; and routing the stored data to other WSN.

In one embodiment, the method further comprises requesting the coordinator MCU for receiving data; and pooling the request made by the routing MCU.

Brief Description of the Drawings

This invention will be described by way of non-limiting embodiments of the present invention, with reference to the accompanying drawings, in which:

FIG. 1 illustrates a typical wireless sensor network (WSN);

FIG. 2 illustrates a wireless sensor network (WSN) in accordance with one embodiment of the present invention;

FIG. 3 illustrates a WSN in accordance with another embodiment of the present invention;

FIG. 4 illustrates a schematic diagram showing the architecture of a site coordinator in accordance with one embodiment of the present invention; and

FIG. 5 illustrates a flow diagram of the coordinator in accordance with one embodiment.

Detailed Description of the Invention

In line with the above summary, the following description of a number of specific and alternative embodiments is provided to understand the inventive features of the present invention. It shall be apparent to one skilled in the art, however that this invention may be practiced without such specific details. Some of the details may not be described at length so as not to obscure the invention. For ease of reference, common reference numerals will be used throughout the figures when referring to the same or similar features common to the figures.

FIG. 2 illustrates a wireless sensor network (WSN) **200** in accordance with one embodiment of the present invention. The WSN **200** comprises a main coordinator **210**, a plurality of site coordinator **220**, a plurality of routers **240** and sensor motes **250** for each coordinator **210**, **220**. Briefly, the coordinators that include the main coordinator **210** and the site coordinator **220**, each comprises generally a microcontroller (MCU), a memory unit, a transceiver and power source. The microcontroller works in conjunctions with the memory unit controls the general operations of the coordinator and process data acquired from the sensor motes **250**. The transceiver is provided for wireless communications between a coordinator and other coordinators as well as the sensor motes **250**. The power source for powering up the coordinator is preferably portable power sources, such as battery, capacitor or the like, to allows the coordinators to be deployed without any geographical limitations. More preferably, the power source may incorporate a solar panel or any energy harvesting means to prolong the period for power source replacement. Each of the sensor motes **250** comprise one or more sensors that collectively acquires and gathers the relevant data for transmitting to the coordinators. The sensors include imaging sensor, thermometer, and many others

depending on the type of information required for that field. The wireless sensor network **200** is clustered into a plurality of smaller WSN **290**, wherein each of the WSN **290** is managed by a main coordinator **210** or site coordinator **220**. Similar to an ordinary WSN, data collected by the sensor motes **250** are forwarded to the respective coordinator **210**, **220** via the nearest router **240**. The main coordinator **210** is a WSN coordinator integrated with one or more communication interface, such as Wi-Fi and GSM, for communicating with foreign networks. Each site coordinator **220** on the other hand is couple with a router **240** for routing the collected data. As each clustered network is relatively smaller, it can now be easier to manage and the power consumed in each network is relatively lower. Further, as the number of hops has been increased by the clustered smaller networks each having its own coordinator **210**, **220** within a small WSN. It can be realized that when a relatively small WSN, each deploys with a coordinator for managing the data flow, is used, distributed power management controls can also be achieved to offer an efficient use of resources on the coordinator and routers by separating the sensor motes into cluster. On top of the resources management, which includes power, memory managements, the smaller WSN **290** permits expansion for large-scale deployment when needed.

FIG. 3 illustrates a WSN **300** in accordance with another embodiment of the present invention. The WSN **300** comprises a main coordinator **310**, a plurality of site coordinator **320**, a plurality of routers **340** and sensor motes **350** for each coordinator **310**, **320**. The WSN **300** operates in substantially a same way as the WSN **200** of **FIG. 2**, where WSN **300** too is clustered into a plurality of smaller WSN **390**, **395**, wherein each of the WSN **390**, **395** is managed by the main coordinator **310** or the site coordinator **320** respectively. Operationally, not all WSN **390**, **395** are running at the same time. In **FIG. 3**, the WSNs **390** are in sleep mode while the WSN **395** is in operating mode. The sleep

FIG. 4 illustrates a schematic diagram showing the architecture of a site coordinator **400** in accordance with one embodiment of the present invention. The site coordinator **400** comprises a coordinator microcontroller **410**, a routing microcontroller **420** and a memory block **430**. Operationally, the coordinator microcontroller **410** initializes its I2C module as default Slave. The routing microcontroller **420** on the other hand initializes its I2C module as default Master, as opposed to the conventional WSN routings where the I2C module is initialized as default Slave for routing all transmissions it receives. When the coordinator microcontroller **410** establishes a new WSN Personal Area Network (PAN), and set as a Slave to the network organizes its child motes and transfers data. During operations, the coordinator microcontroller **410** is usually busying with its own PAN data handling. The memory block unit **430** is adapted in between the coordinator microcontroller **410** and the routing microcontroller **420** for handling the data acquired by the coordinator microcontroller **410**. When time suits, the routing microcontroller **420** reads the data stored in the memory block and route it out accordingly. Further, the availability of memory block **430** also reduces the risk of losing data during the operations when it is interrupted

In the present embodiment, the coordinator **400** adapted two-wire I2C interface for communication between the coordinator microcontroller **410** and the routing microcontroller **420**. The two-wire I2C interface includes a bidirectional data line and a bidirectional clock line. The bidirectional clock line is also connected to the memory block **430**

FIG. 5 illustrates a flow diagram of the coordinator **400** in accordance with one embodiment. The operations are conducted among coordinating microcontroller **410**, routing microcontroller **420** and the memory block **430**. At step **510**, data are transferred from other WSN network to the routing microcontroller **420**. At step **512**, the routing microcontroller **420** sets I2C as Master and the coordinator microcontroller **410** sets I2C as Slave. At step **514**, the data received by the routing microcontroller **420** is stored at the memory block **430**. The memory block **430** acknowledges receipt and stored of the data at step **516**. The routing microcontroller **420** requests the coordinator microcontroller **410** to receive data at step **518**. The request is polled at step **520** at the coordinator microcontroller **410**. At step **522**, the coordinator microcontroller **410** is engaged for handling and coordinating the pooling requests from the routing microcontroller **420**. A negative acknowledgement (NACK) is according feedback to the routing MCU **420** to indicate that the coordinator MCU **410** is busy and not ready to receive new data at step **524**. At step **526**, the routing microcontroller **420**

sets the I2C to slave and standby mode, and the coordinator microcontroller **410** sets I2C as Master. Still at step **526**, the coordinator microcontroller **410** reads the stored data from the memory block **430**. At step **528**, the memory block **430** acknowledges the coordinator. The stored data is then relay a new network accordingly to at step **530**. Such method provides a simple one way data transfer technique for the coordinator **400** for transmitting data. Such method can be used to transfer data in the other directions.

The present invention is adapted with system and method suitable for precision agriculture, among others.

The present invention, in one embodiment, provides a WSN clustered into a plurality of site WSNs, each site WSN is limited in a relatively smaller sensor network size and manages by a site coordinator for coordinating data transmission on an ad-hoc or mesh network basis. Data accumulated by the site coordinator is ultimately routed to a main coordinator that generally provides a long range communication interface. As the WSN is clustered, the site WSN can be managed as a single WSN, where the power drawn by each site WSN can be managed effectively by putting one or more of the site WSNs in sleep mode when others are operating. The data collected by each site coordinator is temporary maintained in a data storage unit integrated in the site coordinator, and when appropriate, the data is routed to the main coordinator for transmission.

In another embodiment, the present invention provides a site coordinator having a coordinating microcontroller (MCU), a routing MCU and a storage unit. The coordinating MCU is provided to coordinate the collections and storage the acquired data from the sensor network in the storage unit. When appropriate, the stored data is routed accordingly. The site

coordinator uses a I2C bus 2 wire connection for communication between the coordinating MCU, routing MCU and the storage unit.

In yet another embodiment, the present invention provides a method of transmitting data and command between both microcontrollers within the site coordinator device. The synchronization routine offered minimizing data clashing and data lost.

While specific embodiments have been described and illustrated, it is understood that many changes, modifications, variations and combinations thereof could be made to the present invention without departing from the scope of the invention.

Claims:

1. A wireless sensor network (WSN) (200) having a main coordinator (210), the WSN (100) comprising:

a plurality of site coordinators (220), each forms a site WSN (290) and functioned by its own, and collectively, the plurality of site WSNs (290) form the WSN (200),

wherein each site coordinator (220) is operable to collect and store data collected/acquired from the respective site WSN (290) and to route out the collected/acquired data to the main coordinator (210) as appropriately.

2. The WSN (200) according to claim 1, wherein operationally, each site WSN (290) works independently, where one of the site WSNs (395) is operable in a sleep mode while other site WSNs (390) are operable in an operating mode.

3. The WSN (200) according to claim 1, wherein the site coordinator (220) is integrated with a routing unit.

4. The WSN (200) according to claim 1, wherein the WSN (200) is expandable by including one or more site WSN (290), each manages by a site coordinator (220).

5. A site coordinator (400) of a site WSN (290), the site coordinator (400) comprising:

a data storage unit (430);

a coordinator microcontroller (MCU) (410) for coordinating data collected/acquired within the site WSN (290); and

a routing MCU (420) for routing the collected/acquired data collectively to other site WSN (290),

wherein the data collected/acquired through the coordinator MCU (410) is stored in the data storage unit (430), and the collected/acquired data are routed to other WSN (290) as appropriately through the routing MCU (420).

6. The site coordinator (400) according to claim 5, wherein the coordinating MCU (410), the routing MCU (420) and the data storage unit (430) are interconnected through I2C connection.

7. A method of collecting/acquiring data from a WSN (290), the method comprising:

initializing (512) a routing MCU (420) as master;

initializing (512) a coordinating MCU (410) as slave;

storing (514) the collected/acquired data into a data storage unit (430); and

routing (530) the stored data to other WSN.

8. The method according to claim 7, further comprising:

requesting (518) the coordinator MCU (410) for receiving data; and

pooling (520) the request made by the routing MCU (420).

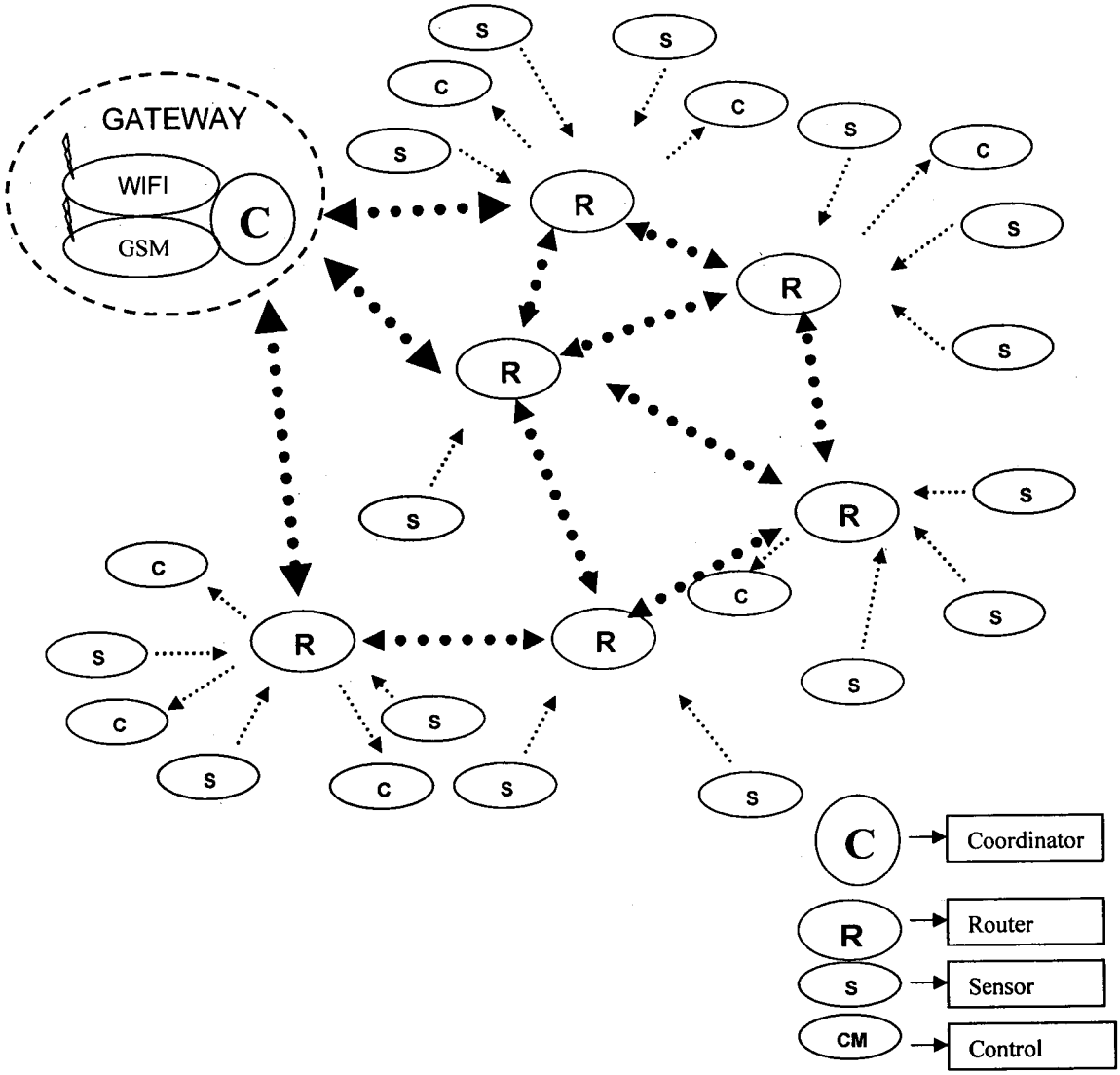

FIG. 1 (PRIOR ART)

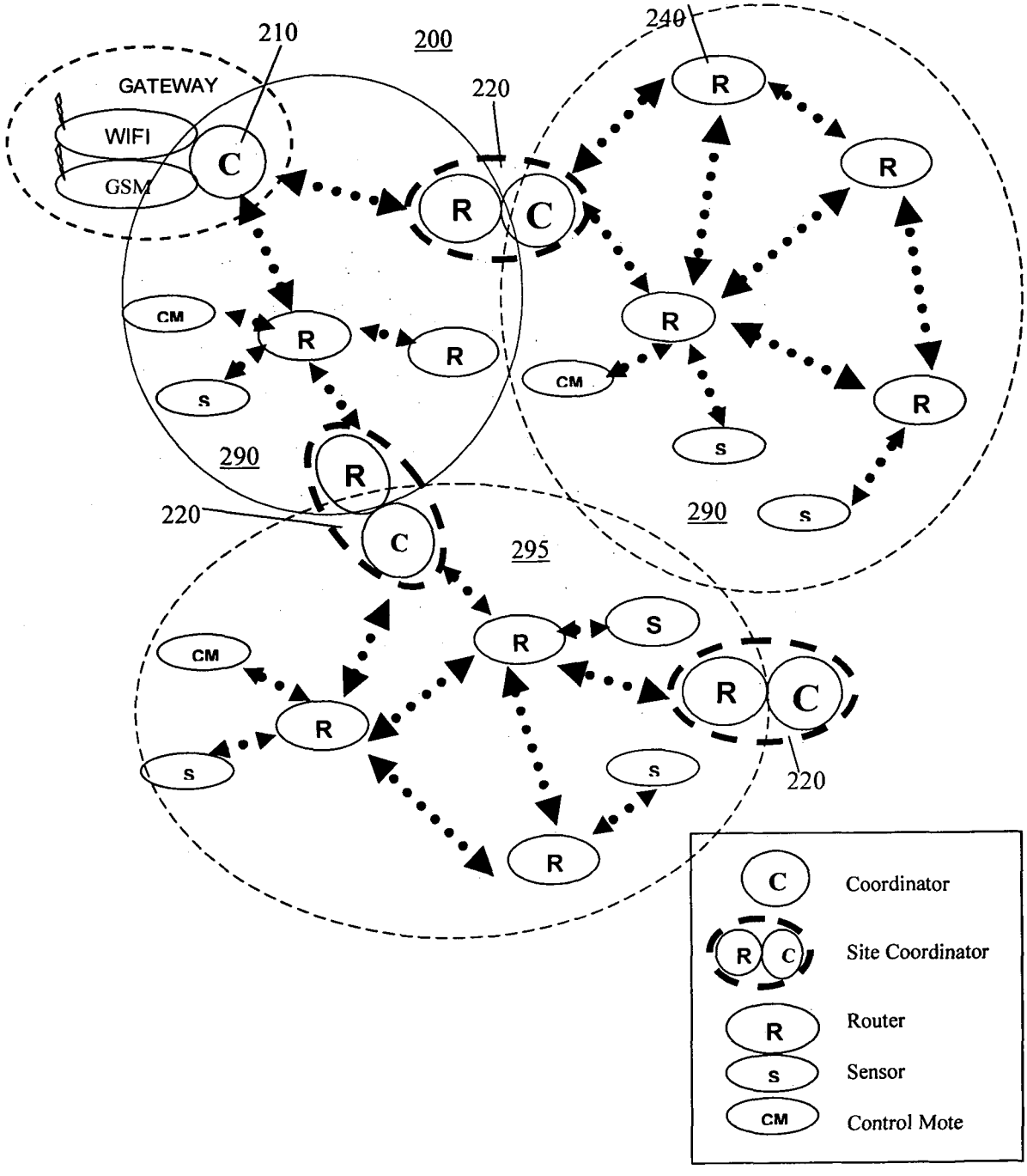
210
200
240
GATEWAY
WIFI
GSM
C
220
R
C
R
R
R
CM
R
R
S
290
R
220
C
295
290
S
CM
R
R
C
R
S
S
220
R
C
Coordinator
R C
Site Coordinator
R
Router
S
Sensor
CM
Control Mote

FIG. 2

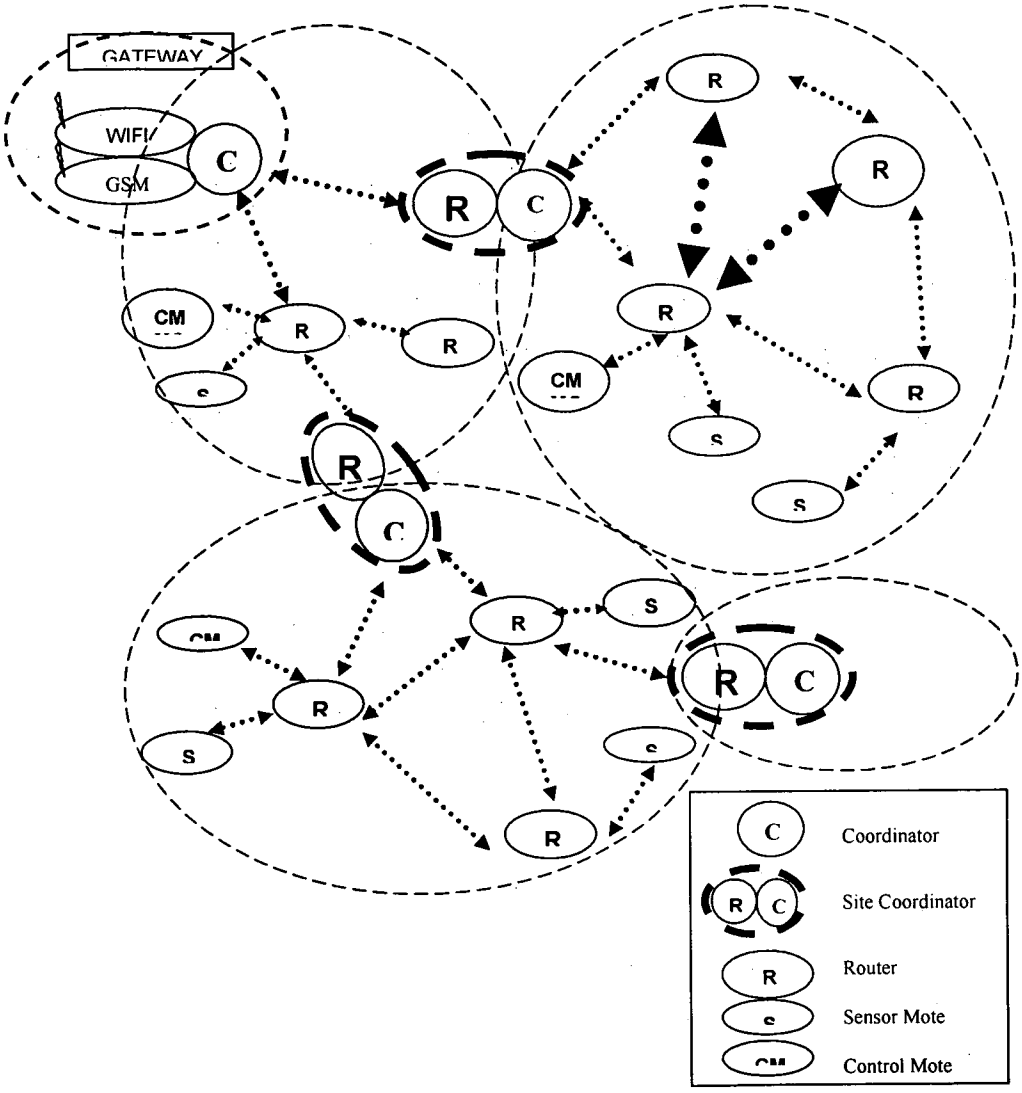
GATEWAY
WIFI
GSM
C
R
CM
S
Coordinator
Site Coordinator
Router
Sensor Mote
Control Mote

FIG. 3

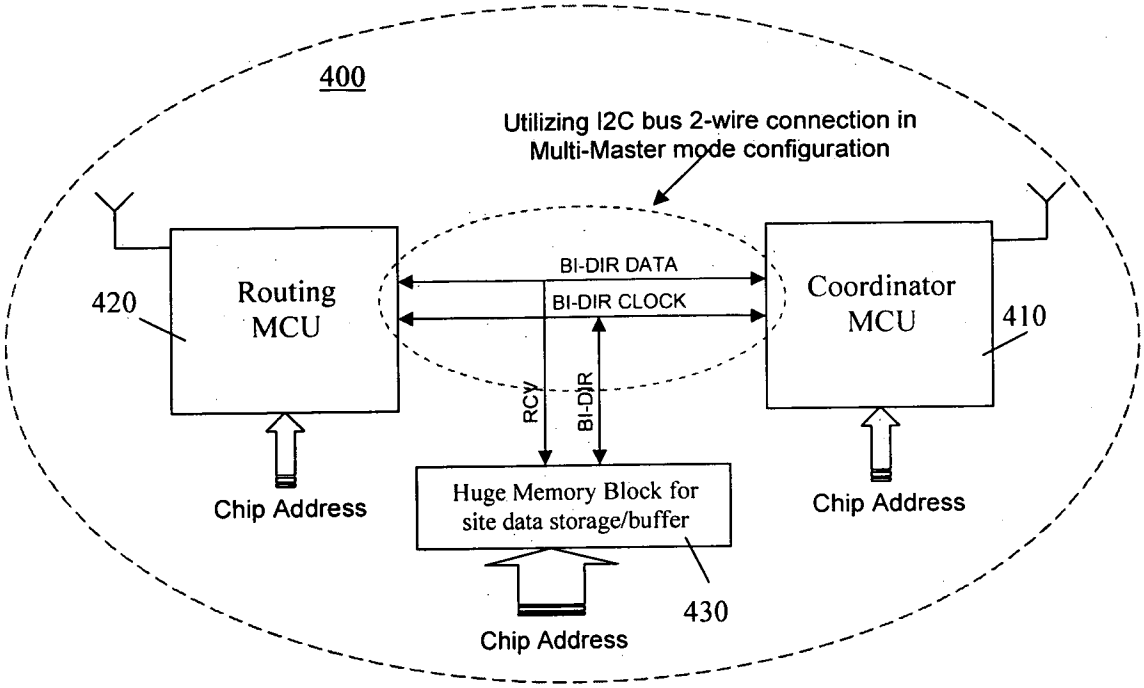
400
Utilizing I2C bus 2-wire connection in
Multi-Master mode configuration
420
Routing
MCU
BI-DIR DATA
BI-DIR CLOCK
Coordinator
MCU
410
RCV
BI-DIR
Chip Address
Huge Memory Block for
site data storage/buffer
Chip Address
430
Chip Address

FIG. 4

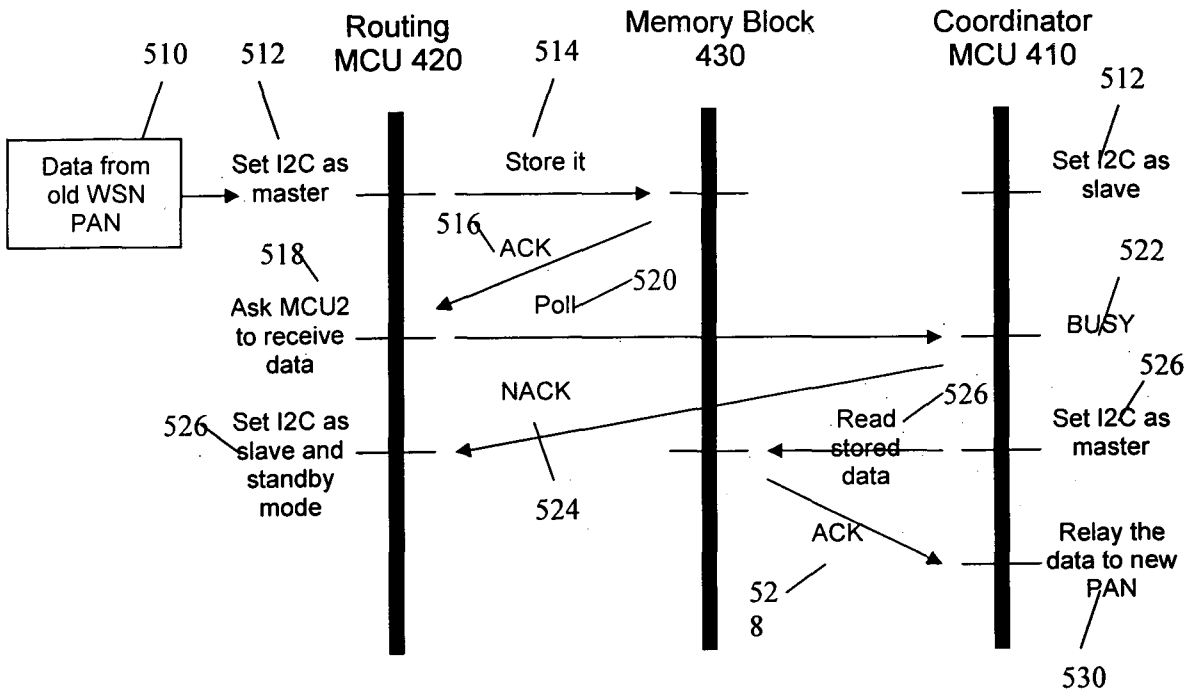
Routing MCU 420
Memory Block 430
Coordinator MCU 410
510
512
514
512
Data from old WSN PAN
Set I2C as master
Store it
Set I2C as slave
516
ACK
518
520
522
Ask MCU2 to receive data
Poll
BUSY
526
NACK
526
526
Set I2C as slave and standby mode
Read stored data
Set I2C as master
524
ACK
Relay the data to new PAN
528
530

FIG. 5