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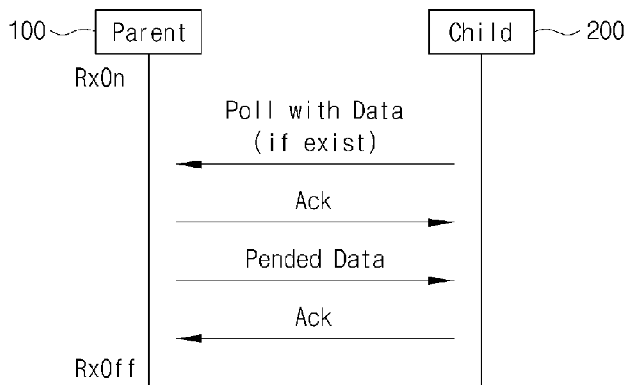
(54) **Title**: NON-BEACON MODE ZIGBEE SENSOR NETWORK SYSTEM FOR LOW POWER CONSUMPTION AND NETWORK COMMUNICATION METHOD THEREOF

[Fig. 3]



(57) **Abstract**: Disclosed herein is a non-beacon mode low-power ZigBee sensor network system and network communication method thereof. The method between a parent node and a child node constituting the non-beacon mode ZigBee sensor network system includes providing polling interval information to a parent node if there is a request for network participation from the child node, and performing, by the parent node, network communication with the child node by determining a time point of a polling request from the child node based on the polling interval information to maintain a wake-up state only at the time point of the polling request from the child node while maintaining a sleep state for a remaining period. The system can reduce power consumption of the parent node in network communication. The system guarantees symmetrical power consumption between the parent node and the child node, thereby preventing network instability.

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Description

NON-BEACON MODE ZIGBEE SENSOR NETWORK SYSTEM FOR LOW POWER CONSUMPTION AND NETWORK COMMUNICATION METHOD THEREOF

Technical Field

[1] The present invention relates to a non-beacon mode low-power ZigBee sensor network system and network communication method thereof. More particularly, the present invention relates to a non-beacon mode low-power ZigBee sensor network system and network communication method thereof, which realizes low power communication through reduction in wake-up time of a parent node constituting a ZigBee sensor network system.

Background Art

[2] Recently, with increasing interest in a ubiquitous environment, a sensor network has been actively studied. In sensor networking, ZigBee is provided for Wireless Personal Area Networks (WPANs) and is recognized as an optimal technology for establishing a low-power and very low-cost network. Thus, it is believed that ZigBee will become a core technology in applications such as office automation, factory automation, home networks, and the like. Furthermore, ZigBee will be useful as a sensor network solution built not only in homes or indoors, but also in various regions where environmental changes, such as forest fires, disasters, and the like, are difficult to monitor in person. In most of such applications, ZigBee devices operate based on battery power. Accordingly, the most important factor in the sensor network is low power consumption.

[3] ZigBee is a standard newly defined from a network layer by introduction of the Physical Layer (PHY) Protocol and the Medium Access Control (MAC) layer of the Institute of Electrical and Electronic Engineers (IEEE) 802.15.4 standard.

[4] The ZigBee standard has a stack architecture that comprises an application layer, a network layer, the MAC layer, and the PHY layer.

[5] The PHY layer is defined according to the IEEE 802.15.4 standard and provides an interface between the MAC layer and physical channels through RF firmware and RF hardware. The PHY layer uses the 2.4 GHz band, the 869 MHz band and the 915 MHz band, and supports Offset Quadrature Phase Shift Keying (OQPSK) modulations/demodulation. The PHY layer is responsible for activation and deactivation of radio transceivers, energy detection for selected channels, allocation of channel frequency, data transmission/reception, and the like.

[6] The MAC layer is also defined according to the IEEE 802.15.4 standard, controls and

handles all of the physical channels, and is responsible for channel connection.

[7] The network layer builds up a network of the star, cluster-tree or mesh topology, and serves to select a data transmission path between devices.

[8] The application layer provides an Application Programming Interface (API) between the network layer and the application layer to control ZigBee devices or application devices defined by users.

[9] The devices for ZigBee communication can be classified according to function or performance.

[10] According to performance, the ZigBee devices can be classified into a Full Function Device (FFD) and a Reduced Function Device (RFD). The full function device (FFD) can function as a ZigBee coordinator, ZigBee router, and ZigBee terminal device. The FFD supports all of network topologies, such as star topology, peer-to-peer topology, and cluster-tree topology.

[11] According to function, the ZigBee devices can be classified into a coordinator, a router, and a terminal device. A single coordinator is provided to each network and forms the root of the network.

[12] The router is a full function device (FFD) component of a ZigBee network and acts to temporarily pass data from other devices.

[13] The terminal device is generally constituted by the reduced function device (RFD) and cannot act as the coordinator or the router. Rather, the terminal device can perform very simple functions and supports a limited protocol function.

[14] The classification of the ZigBee devices is directed to reduction in implementation costs. Particularly, since the terminal device is implemented most frequently, it is designed to provide only an essential function without any other functions in order to reduce a price thereof as much as possible.

[15] Here, the coordinator and the router are parent nodes with respect to the terminal device, and the terminal device is a child node with respect to the coordinator or the router. Further, the router becomes a child node with respect to the coordinator and becomes a parent node with respect to the terminal device. Particularly, the terminal device only functions as the child node without a function of allocating a network address, which is a function of the parent node.

[16] On the other hand, the ZigBee network generally operates in two modes, that is, a beacon mode and a non-beacon mode. In the beacon mode network, nodes are synchronized by a periodic beacon message. In the non-beacon mode network, however, the periodic beacon message is not used. Since the non-beacon mode network does not require construction of a superframe with transmission and reception of the periodic beacon, it can be established more simply. Since the topologies or configurations of the beacon mode network and the superframe are not directly related to the present

invention and are well known to those skilled in the art, a detailed description thereof will be omitted herein.

[17] Figs. 1(a) and 1(b) show data transmission procedures in a conventional non-beacon mode network.

[18] Fig. 1(a) shows a data transmission procedure from a child node 20 to a parent node 100, and Fig. 1(b) shows a data transmission procedure from the parent node 10 to the child node 10.

[19] As shown in Fig. 1(a), since the parent node 10 operates in a wake-up state in the conventional non-beacon mode network, data is directly transmitted (sent) from the child node 20 to the parent node 10 without an acknowledgement or separate operation if there is a need for data transmission from the child node 20. Then, the parent node 10 transmits to the child node 20 an acknowledgement message (Ack) which indicates the reception of data transmitted from the child node 20.

[20] As shown in Fig. 1(b), in the conventional non-beacon mode network, the parent node 10 cannot send data if there is no polling request (Poll) from the child node even in the case where there is a need for data transmission to the child node 20. When there is a polling request (Poll) from the child node 20, the parent node 10 receives the polling request and transmits an acknowledgement message (Ack) to the child node 20. Further, the parent node 10 transmits data to the child node 20. Then, the child node 20 transmits to the parent node 10 an acknowledgement message (Ack) which indicates the reception of the data transmitted from the parent node 10.

[21] The aforementioned non-beacon mode network has a simpler network architecture than the beacon network and does not require the nodes to be maintained in a wake-up state or synchronized for periodic processing of the beacon message. However, since it is necessary to guarantee responses to the periodic polling request and random data transmission from the child node, the non-beacon mode network must await data reception in the wake-up state. This will be described in more detail with reference to Fig. 2.

[22] As shown in Fig. 2, in order to respond to a periodic polling request having a predetermined interval I and random data transmission from the child node, the parent node must be maintained in the wake-up state. This is very inefficient in view of power consumption. Further, this requirement causes asymmetrical power consumption between the parent node and the child node. In other words, the parent node uses more power than the child node. Such asymmetrical power consumption between the parent node and the child node can lead to unstable network connectivity. Accordingly, there is a need for a non-beacon mode low-power network that enables symmetrical power consumption between the parent node and the child node, thereby reducing network power consumption.

Disclosure of Invention

Technical Problem

[23] Therefore, the present invention is conceived to solve the problems of the related art and an aspect of the present invention is to provide a non-beacon mode low-power ZigBee sensor network system and network communication method thereof, which can overcome the problems of the related art.

[24] Another aspect of the present invention is to provide a non-beacon mode low-power ZigBee sensor network system and network communication method thereof, which can reduce power consumption.

[25] A further aspect of the present invention is to provide a non-beacon mode low-power ZigBee sensor network system and network communication method thereof, which can prevent or minimize network instability.

Technical Solution

[26] In accordance with one embodiment of the present invention, the above and other aspects of the present invention can be accomplished by the provision of a network communication method between a parent node and a child node constituting a non-beacon mode ZigBee sensor network system, which includes: providing, by the child node, polling interval information to the parent node if there is a request from the child node for network participation; and performing, by the parent node, network communication with the child node in a way of maintaining a wake-up state only at a time point of a polling request from the child node while maintaining a sleep state for a remaining period by determining the time point of the polling request from the child node based on the polling interval information.

[27] The parent node may frame and update a time table based on the polling interval information of the child node, and determine whether the parent node enters the wake-up state or the sleep state based on the time table, the time table including first time information including information of an elapsed time from a time point of a last issued polling request to a current wake-up time point and second time information including information of a remaining period from the current wake-up time point to a next predicted polling request of the child node.

[28] Framing and updating the time table may be carried out in the wake-up state of the parent node.

[29] The polling interval information of the child node may be transferred to the parent node by being embedded in an MLME-ASSOCIATE.request message issued for the network participation of the child node from a higher layer of a Media Access Control (MAC) layer of the child node, and the parent node may obtain the polling interval information of the child node while processing an MLME-ASSOCIATE.indication

message transferred from a MAC layer of the parent node to a higher layer thereof.

[30] The sensor network system may include a plurality of child nodes and at least one parent node.

[31] The first time information may include plural pieces of time information about elapsed times from time points of last polling requests of the respective child nodes to a wake-up time point of the at least one parent node, and the second time information may include plural pieces of time information about remaining periods from the wake-up time point of the at least one parent node to time points of directly next predicted polling requests of the respective child nodes.

[32] A wake-up time of the parent node may be determined based on shortest remaining period information among the plural pieces of time information included in the second time information.

[33] Data transmission from the parent node to the child node may be carried out after the polling request of the child node, and data transmission from the child node to the parent node may be carried out by being embedded in the polling request of the child node.

[34] In accordance with another embodiment of the present invention, a non-beacon mode ZigBee sensor network system includes: a plurality of child nodes, each providing polling interval information when requesting network participation, and performing network communication via a periodic polling request; and at least one parent node performing the network communication with the child nodes by a wake-up state at a time point of a polling request from each of the child nodes while maintaining a sleep state during a remaining period, for which the polling request from each of the child nodes is not predicted, by determining the time point of the polling request from each of the child nodes based on the polling interval information provided by each of the child nodes.

[35] The parent node may frame and update a time table, and determine whether the parent node enters the wake-up state or the sleep state based on the time table, the time table including first time information including plural pieces of time information about elapsed times from time points of last issued polling requests of the respective child nodes to a wake-up time point of the at least one parent node and second time information including plural pieces of time information about remaining periods from the time point of the at least one parent node to time points of directly next predicted polling requests of the respective child nodes.

[36] Framing and updating the time table may be carried out in the wake-up state of the parent node.

[37] A wake-up time of the parent node may be determined based on shortest remaining period information among the plural pieces of time information included in the second

time information.

[38] The polling interval information of each of the child nodes may be transferred to the at least one parent node by being embedded in an MLME-ASSOCIATE.request message issued for network participation from a higher layer of a MAC layer of each of the child nodes, and the at least one parent node may obtain the polling interval information of each of the child nodes while processing an MLME-ASSOCIATE.indication message transferred from a MAC layer of the at least one parent node to a higher layer thereof.

[39] Data transmission from the at least one parent node to each of the child nodes may be carried out after the polling request from each of the child nodes, and data transmission from each of the child nodes to the at least one parent node may be carried out by being embedded in the polling request of each of the child nodes.

Advantageous Effects

[40] According to one embodiment of the present invention, the sensor network system can reduce power consumption caused by maintaining a wake-up state of a parent node in network communication. Therefore, the sensor network system according to this embodiment of the invention consumes low power in network communication. Further, the network system can prevent or minimize network instability by guaranteeing symmetrical power consumption between the parent node and a child node.

Brief Description of Drawings

[41] The above and other aspects, features and advantages of the present invention will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

[42] Figs. 1(a) and 1(b) are diagrams of data transmission procedures in a conventional non-beacon mode network;

[43] Fig. 2 is a timing chart of a polling request of a child node and a wake-up state of a parent node in the conventional non-beacon mode network;

[44] Fig. 3 is a diagram of a non-beacon ZigBee sensor network system and a data transmission procedure according to one embodiment of the present invention;

[45] Figs. 4 and 5 are diagrams of network participation procedures of the parent node and the child node of Fig. 3;

[46] Fig. 6 shows a time table for determining a wake-up time of the parent node of Fig. 3 according to polling intervals of the child nodes; and

[47] Fig. 7 is a timing chart of a process of waking up the parent node according to the time table of Fig. 6 and the polling requests of child nodes.

Best Mode for Carrying out the Invention

[48] Hereinafter, exemplary embodiments of the present invention will be described in

detail with reference to the accompanying drawings. It should be noted that the following embodiments are given for thorough understanding of the present invention by a person having ordinary knowledge in the art without any intension of limiting the scope of the present invention.

[49] Herein, the term “parent node” refers to a coordinator or a router as well-known to a person having ordinary knowledge in the art, and the term “child node”refers to a terminal device as well-known to a person having ordinary knowledge in the art, unless they are differently defined in the specification. The terminal device can also be referred to as a sensor node, an end device, a network device or the like.

[50] Fig. 3 is a diagram of a non-beacon ZigBee sensor network system and a data transmission procedure according to one embodiment of the present invention.

[51] Referring to Fig. 3, the non-beacon ZigBee sensor network system of this embodiment includes a parent node 100 and a child node 200 that carry out network communication via a predefined protocol. The network system may include at least one parent node 10 and multiple child nodes 200.

[52] Basically, the network system according to this embodiment of the invention is directed to reduce power consumption via minimization of asymmetrical power consumption between the parent node and the child node by allowing the parent node 100 to maintain a wake-up state only when the child node 200 issues a polling request.

[53] Each of the multiple child nodes 200 provides polling interval information to the parent node 100 when requesting network participation with the parent node 100, and carries out network communication via a periodic polling request when participating in the network. The child node 200 carries out similar operations to those of a conventional child node except for providing the polling interval information to the parent node 100 when requesting the network participation. In other words, the child node 200 operates similarly to the conventional child node in that the child node 200 carries out the network communication with the parent node 100 via the periodic polling request.

[54] The parent node 100 receives the polling interval information from the child nodes 200 and determines time points of issued polling requests of the child nodes 200. The parent node 100 enables low power consumption of the sensor network system by maintaining a wake-up state at the time points of the polling requests from the child nodes 200 while maintaining a sleep state during a remaining period, for which the polling requests of the child nodes 200 are not predicted. A method of determining the time point of the polling request from each child node 200 will be described below not only in the case where a single childe node 200 is provided to the network system, but also in the case where multiple child nodes 200 are provided thereto.

[55] The network communication as described above can provide one problem. In a con-

ventional network system, when the child node 200 sends data (a data packet) to the parent node 100, the data is sent randomly without time limitation. Such random data transmission of the conventional network system is permitted since a parent node of the network system maintains the wake-up state. According to the embodiment of the invention, however, the parent node 100 alternates between the wake-up state and the sleep state, so that the random data transmission from the child node 200 to the parent node 100 is not permitted. In order to overcome this problem, the sensor network system according to this embodiment is configured to allow the child node 200 to send data to the parent node 100 by embedding the data in the polling request when issuing the polling request, if there is a need for data transmission from the child node 200. Namely, the child node 200 may transmit data to the parent node 100 by embedding the data in a polling request message.

[56] Assume that the parent node 100 knows a time point of an issued polling request of the child node 200 through interchange of the polling interval information therebetween. Then, data transmission between the parent node 100 and the child node 200 is carried out as follows.

[57] Firstly, the parent node 100 maintains a sleep state in normal times, and enters a wake-up state at the time point of the polling request from the child node 200. As a result, the parent node 100 enters a reception-enabled state RxOn. At this time, a polling request message (Poll) issued from the child node 200 is transferred to the parent node 100. The message and data transmission procedure of between the child node 200 and the parent node 100 is well-known to those skilled in the art.

[58] The polling request message may include data to be transmitted from the child node 200 to the parent node 100. In other words, the polling request (Poll with Data) having data embedded therein may be transmitted from the child node 200 to the parent node 100.

[59] When receiving the polling request (Poll with Data), the parent node 100 issues and transmits to the child node 200 an acknowledgement message (Ack) which indicates the reception of the polling request (Poll with Data). Then, the parent node 100 transmits data (Pended Data) to the child node 200.

[60] When receiving the data from the parent node 100, the child node 200 issues and transmits to the child node 200 an acknowledgement message (Ack) which indicates the reception of the data.

[61] After a series of procedures described above, the parent node 100 enters the sleep state and is switched to a reception-disabled state RxOff. The sleep state and the reception-disabled state of the parent node 100 are continued until a next polling request from the child node 200.

[62] As described above, as the parent node 100 alternates between the sleep state and the

wake-up state instead of maintaining the wake-up state, it is possible to reduce power consumption compared with the conventional network system.

[63] Figs. 4 and 5 are diagrams of procedures for network participation of the child node and the parent node.

[64] Fig. 4 shows a summarized procedure for network participation of the child node 200, and Fig. 5 shows a summarized procedure for network participation of the parent node 100.

[65] Other procedures unnecessary in description of the invention or apparent to those skilled in the art are not shown in Figs. 4 and 5. Therefore, it should be noted that the present invention includes these procedures although a description thereof is omitted herein.

[66] Referring to Fig. 4, a network reset or initialization message (or command) MLME-RESET.request is issued from a higher layer of the MAC layer to the MAC layer in the child node 200 for network participation. Herein, the term “higher layer” includes the application layer and the network layer, and may be used as a general term referring to any layer above the MAC layer.

[67] Then, the MAC layer of the child node 200 issues a confirmation message MLME-RESET.confirm with respect to the network reset or initialization message MLME-RESET.request to the higher layer.

[68] Then, the higher layer interchanges scan messages MLME-SCAN.request and MLME-SCAN.confirm with the MAC layer for searching an activated network. Basically, the child node reads out all channels of associated frequencies in the three frequency bands defined by the IEEE 802.15.4 standard. In other words, physical channels of a previously defined network are searched.

[69] If the objective is to connect with an existing network, the same physical channel as that of the existing network is selected, and if the objective is to create an independent network, a physical channel of a deactivated network is selected. Such network policy and channel selection are defined to be determined in the higher layer above the MAC layer for networking flexibility of the IEEE 802.15.4 standard.

[70] The IEEE 802.15.4 standard supports 27 physical channels, in which a network of each channel is created with a predetermined energy different from those of other networks of other channels. Here, a child node requesting network participation can perform energy detection (ED) with respect to all channels given by the IEEE 802.15.4 standard according to the network policy. The energy detection (ED) may be used to detect a channel for a deactivated PAN network in order to create a network.

[71] Then, the higher layer of the child node 200 issues and transfers a message for network association to the MAC layer, that is, a message MLME-ASSOCIATE.request for address assignment from the parent node 100.

[72] The IEEE 802.15.4 standard uses a 64-bit unique address, and a 16-bit address that can be allocated from a parent node. The message MLME-ASSOCIATE.request is a message that has a 64-bit unique address and is directed to receive a 16-bit address from the parent node. In other words, the message MLME-ASSOCIATE.request is the message for address request. The 16-bit address employs a short data frame of the physical layer and is known as convenient in development of an addressed-based routing protocol. When the 16-bit address is allocated from the parent node 100 to the child node 200, the child node 200 is connected to the network.

[73] Here, according to one embodiment of the present invention, the child node 200 may be configured to transmit to the parent node 100 the message MLME-ASSOCIATE.request for address requesting with polling interval information (Poll interval or Poll period, hereinafter, "Poll interval") inserted into the message.

[74] It should be noted that other methods may be conceived to transfer the polling interval from the child node 200 to the parent node 100.

[75] The polling interval information "Poll interval" inserted into the message MLME-ASSOCIATE.request is transferred to the MAC layer (MAC) of the child node 200, and is transferred from the MAC layer (MAC) of the child node 200 to the physical layer (PHY) of the child node 200 via a message PD-DATA.request. Then, the polling interval information is transferred from the physical layer (PHY) of the child node 200 to the physical layer (PHY) of the parent node 100 via a message ASSOCIATION REQUEST.

[76] Referring to Fig. 5, the polling interval information "Poll interval" is transferred from the physical layer (PHY) of the child node 200 to the physical layer (PHY) of the parent node 100 via the message ASSOCIATION REQUEST. Then, the physical layer (PHY) of the parent node 100 transfers the polling interval information to the MAC layer (MAC) of the parent node 100 via a message PD-DATA.indication. Next, the MAC layer (MAC) of the parent node 100 transfers the polling interval information "Poll interval" to a higher layer of the parent node 100 via a message MLME-ASSOCIATE.indication.

[77] Then, the higher layer of the parent node 100 allocates an available 16-bit address to the child node 200 according to the policy of the network (NWK) layer. The parent node 100 can be informed of the polling interval of the child node, which requests network participation, while processing the message MLME-ASSOCIATE.indication. Therefore, the parent node 100 frames a time table based on the polling interval information "Poll interval" and determines the time point of the polling request issued from the child node 200. A method of framing the time table and determining the time point of the polling request in the parent node 100 will be described below with reference to Fig. 6.

[78] Then, transmission procedures of messages MLME-ASSOCIATE.response, DATA.request and ASSOCIATION REQUEST in the parent node 100 are the same as those of the conventional technique. Further, transmission procedures of messages PD-DATA.confirm and MLME-ASSOCIATE.confirm from the parent node 100 in Fig. 4 are also the same as those of the conventional technique. Thus, another detailed description thereof will be omitted herein.

[79] Network integration between the child node 200 and the parent node 100 is completed via the aforementioned procedures. When the child node 200 comprises multiple child nodes 200, the parent node 100 can know the polling intervals of the respective child nodes 200 through such network integration procedures with the respective child nodes 200.

[80] Fig. 6 shows a time table for determining a wake-up time of the parent node 100 according to the polling intervals of the child nodes 200. Here, the wake-up time of the parent node 100 may mean an enabled (activation) time “MAC enable time” of the MAC layer (MAC) of the parent node 100.

[81] Assume that the number of the parent nodes 100 is one and the number of the child nodes 200 is n (n is a certain natural number). Further, “In” indicates a polling interval of each child node 200, “Pn” indicates information of an elapsed time from a time point of a last issued polling request from an n-th child node to a current wake-up time point of the parent node, and “In-Pn” indicates information of a remaining period from the current wake-up time point of the parent node to a time point of a next predicted polling request to be issued from the n-th child node. “T” indicates information about a shortest remaining period (T=min(In-Pn)) among the remaining periods from the wake-up time point of the parent node to respective time points of next predicted polling requests to be issued from first to n-th child nodes.

[82] As shown in Fig. 6, the parent node 100 obtains the plural pieces of polling interval information (I1~In) from the multiple child nodes (Child node 1 ~ Child node n, hereinafter generally referred to as “200”) during network integration, as described above. The parent node 100 frames a time table based on the plural pieces of polling interval information (I1~In).

[83] Firstly, the parent node 100 stores in the time table first time information P which includes plural pieces of time information about elapsed times from time points of last issued polling requests of the respective child nodes 200 to a wake-up time point of the parent node 100. Further, the parent node 100 stores in the time table second time information which includes plural pieces of time information about remaining periods from the wake-up time point of the parent node 100 to time points of directly next predicted polling requests of the respective child nodes 200. Then, the parent node 100 determines a wake-up time of the parent node 100 based on information of a shortest

predicted remaining period (T=min(In-Pn)) among the plural pieces of time information included in the second time information.

[84] For example, assume that a first child node (Child node 1) has a polling interval "I1=10" and provides first time information "P1=3". Namely, it is assumed that a time period corresponding to "3" has elapsed from the last issued polling request of the first child node (Child node 1) to the current time point. Then, second time information "I1-P1" of the first child node (Child node 1) is "7".

[85] Next, assume that a second child node (Child node 2) has a polling interval "I2=4" and provides first time information "P2=0". Namely, it is assumed that the current time point is the time point of the polling request of the second child node (Child node 2). Then, second time information "I2-P2" of the second child node (Child node 2) is "4".

[86] In this manner, after calculating the plural pieces of second time information from the first child node to the n-th child node (Child node n), the information of the shortest remaining period among the plural pieces of second time information is obtained, and next wake-up times are defined and stored in the time table.

[87] Therefore, the parent node 100 again enters the wake-up state based on the minimum period (shortest period) information among the plural pieces of second time information. In this regard, it should be noted that the parent node 100 maintains the sleep state for other periods. Here, if the child node consists of the first and second child nodes (Child node 1, Child node 2), the minimum period information among the plural pieces of second time information is "T=4". Thus, the parent node 100 again enters the wake-up state after a time corresponding to "T=4".

[88] At this time, the first time information (P1) of the first child node (Child node 1) is updated to a time value of "(P1+T)%I1". It necessarily follows that the first time information (P2) of the second child node (Child node 2) is updated to a time value of "(P2+T)%I2". Furthermore, the second time information (I1-P1) of the first child node (Child node 1) and the second time information (I2-P2) of the second child node (Child node 2) are also updated.

[89] In this manner, the first time information of the n-th child (Child node n) is updated to a time value of "(Pn+T)%In" and the second time information (In-Pn) thereof is also updated.

[90] Framing and updating the time table are carried out by the parent node 100 while the parent node 100 maintains the wake-up state. In other words, whenever the parent node 100 is awakened, the parent node 100 calculates the associated time values using a timer, stores the calculated time values in the time table, determines wake-up times according to the reset "T" values, and returns to the sleep state.

[91] Fig. 7 is a timing chart of a process of waking up the parent node according to the time table of Fig. 6 and the polling request of the child node. In Fig. 7, it is assumed

that the child node consists of two child nodes for convenience of understanding.

[92] Referring to Fig. 7, the first child node (Child node 1) has a polling interval I1 and the second child node (Child node 2) has a polling interval I2. Here, the polling interval I2 of the second child node (Child node 2) is longer than the polling interval I1 of the first child node (Child node 1).

[93] Assuming that an arrow (↓) indicates a current wake-up time point of the parent node 100, a directly previous wake-up time point of the parent node 100 becomes a time point of a thirdly issued polling request of the second child node (Child node 2), and the current wake-up time point of the parent node 100 becomes a time point of a fourthly issued polling request of the first child node (Child node 1). Therefore, at the current time point, the first time information (P1) of the first child node (Child node 1) has a time value of "0", and the first time information (P2) of the second child node (Child node 2) has a time value from the time point of the thirdly issued polling request of the second child node (Child node 2) to the current time point.

[94] Further, the second time information I1-P1 of the first child node (Child node 1) has a remaining time value from the current time point to a time point of a fifthly issued polling request of the first child node (Child node 1), and the second time information I2-P2 of the second child node (Child node 2) has a remaining time value from the current time point to a time point of a fourthly issued polling request of the second child node (Child node 2). Accordingly, "T", the shortest remaining period information among the second time information of the first and second child nodes (Child node 1, Child node 2) becomes "I2-P2," that is, the second time information of the second child node (Child node 2). As a result, when the parent node 100 returns to the sleep state after completing the current wake-up state, the parent node 100 again maintains the wake-up state after "I2-P2".

[95] As apparent from the above description, the non-beacon mode sensor network system according to one embodiment of the present invention can reduce power consumption relating to maintenance of a wake-up state of a parent node. Furthermore, the non-beacon mode sensor network system enables symmetrical power consumption between the parent node and a child node, thereby preventing or minimizing network instability.

[96] Although some embodiments have been provided to illustrate the present invention in conjunction with the accompanying drawings, it should be noted that the embodiments are given by way of illustration only and do not limit the scope of the present invention. Further, it will be apparent to those skilled in the art that various modifications, changes, and substitutions can be made without departing from the spirit and scope of the present invention, as defined only by the following claims.

[97]

Claims

[1] A network communication method between a parent node and a child node constituting a non-beacon mode ZigBee sensor network system, the method comprising:
providing, by the child node, polling interval information to the parent node if there is a request from the child node for network participation; and
performing, by the parent node, network communication with the child node in a way of maintaining a wake-up state only at a time point of a polling request from the child node while maintaining a sleep state for a remaining period by determining the time point of the polling request from the child node based on the polling interval information.

[2] The method according to claim 1, wherein the parent node frames and updates a time table based on the polling interval information of the child node, and determines whether the parent node enters the wake-up state or the sleep state based on the time table, the time table comprising first time information including information of an elapsed time from a time point of a last issued polling request to a current wake-up time point and second time information including information of a remaining period from the current wake-up time point to a next predicted polling request of the child node.

[3] The method according to claim 2, wherein framing and updating the time table are carried out in the wake-up state of the parent node.

[4] The method according to claim 3, wherein the polling interval information of the child node is transferred to the parent node by being embedded in an MLME-ASSOCIATE.request message issued for the network participation of the child node from a higher layer of a Media Access Control (MAC) layer of the child node.

[5] The method according to claim 4, where the parent node obtains the polling interval information of the child node while processing an MLME-ASSOCIATE.indication message transferred from a MAC layer of the parent node to a higher layer thereof.

[6] The method according to claim 3, wherein the sensor network system comprises a plurality of child nodes and at least one parent node.

[7] The method according to claim 6, wherein the first time information comprises plural pieces of time information about elapsed times from time points of last polling requests of the respective child nodes to a wake-up time point of the at least one parent node, and the second time information comprises plural pieces of time information about remaining periods from the wake-up time point of the at

least one parent node to time points of directly next predicted polling requests of the respective child nodes.

[8] The method according to claim 7, wherein a wake-up time of the parent node is determined based on shortest remaining period information among the plural pieces of time information included in the second time information.

[9] The method according to claim 3 or 8, wherein data transmission from the parent node to the child node is carried out after the polling request of the child node, and data transmission from the child node to the parent node is carried out by being embedded in the polling request of the child node.

[10] A non-beacon mode ZigBee sensor network system comprising:
a plurality of child nodes, each providing polling interval information when requesting network participation, and performing network communication via a periodic polling request; and
at least one parent node performing the network communication with the child nodes in a way of maintaining a wake-up state at a time point of a polling request from each of the child nodes while maintaining a sleep state during a remaining period, for which the polling request from each of the child nodes is not predicted, by determining the time point of the polling request from each of the child nodes based on the polling interval information provided by each of the child nodes.

[11] The non-beacon mode ZigBee sensor network system according to claim 10, wherein the parent node frames and updates a time table, and determines whether the parent node enters the wake-up state or the sleep state based on the time table, the time table comprising first time information including plural pieces of time information about elapsed times from time points of last issued polling requests of the respective child nodes to a wake-up time point of the at least one parent node and second time information including plural pieces of time information about remaining periods from the time point of the at least one parent node to time points of directly next predicted polling requests of the respective child nodes.

[12] The non-beacon mode ZigBee sensor network system according to claim 11, wherein framing and updating the time table are carried out in the wake-up state of the parent node.

[13] The non-beacon mode ZigBee sensor network system according to claim 12, wherein a wake-up time of the parent node is determined based on shortest remaining period information among the plural pieces of time information included in the second time information.

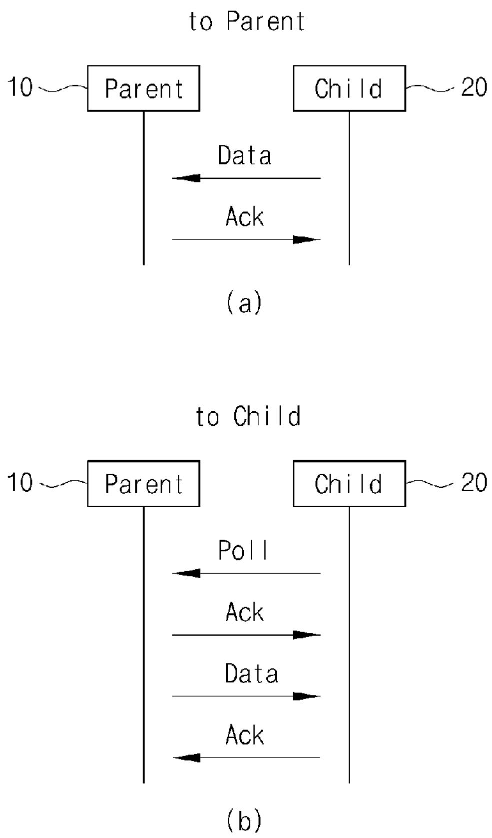
[14] The non-beacon mode ZigBee sensor network system according to claim 10,

wherein the polling interval information is transferred to the parent node by being embedded in an MLME-ASSOCIATE.request message issued for the network participation of the child node from a higher layer of a MAC layer of each of the child nodes.

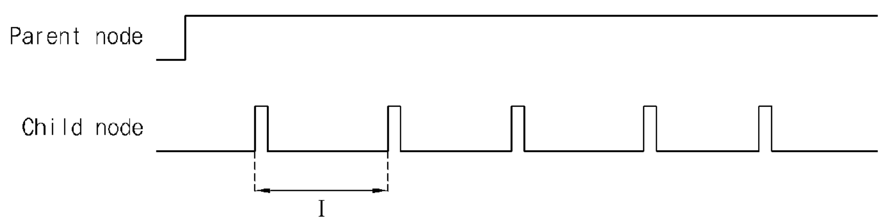
[15] The non-beacon mode ZigBee sensor network system according to claim 14, where the at least one parent node obtains the polling interval information of each of the child node while processing an MLME-ASSOCIATE.indication message transferred from a MAC layer of the parent node to a higher layer thereof.

[16] The non-beacon mode ZigBee sensor network system according to claim 12 or 15, wherein data transmission from the at least one parent node to each of the child nodes is carried out after the polling request from each of the child nodes, and data transmission from each of the child nodes to the at least one parent node is carried out by being embedded in the polling request of each of the child nodes.

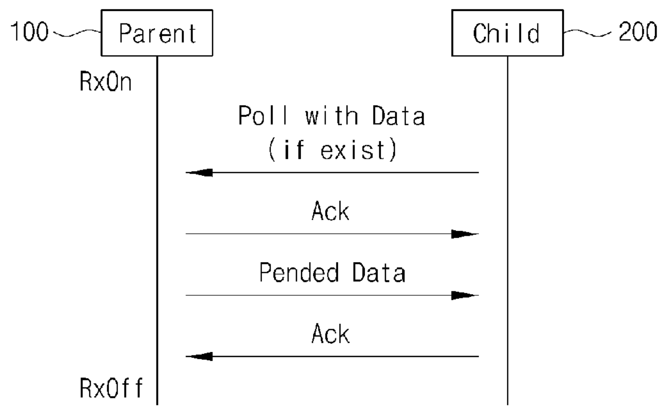
[Fig. 1]



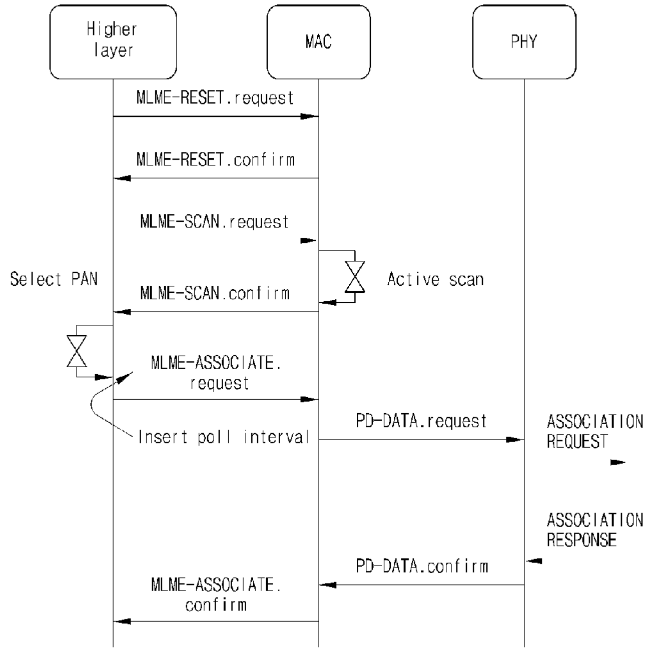
[Fig. 2]



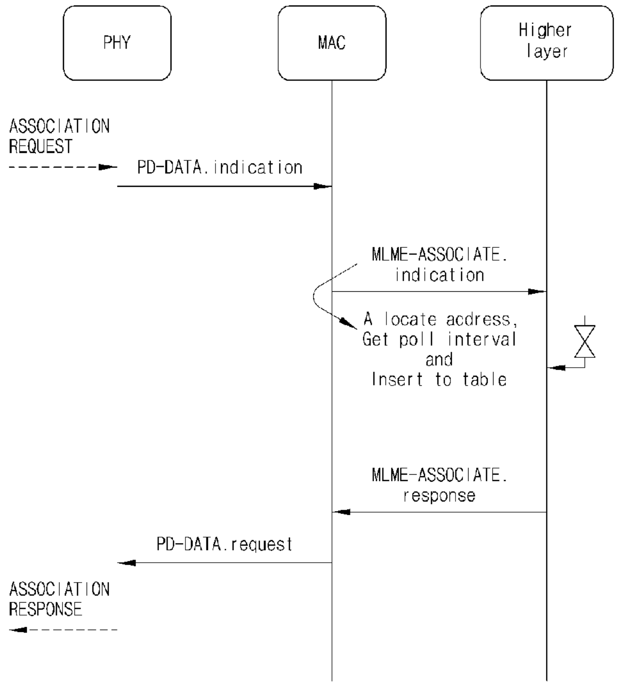
[Fig. 3]



[Fig. 4]



[Fig. 5]



[Fig. 6]

	Polling interval	Time after last wake up	Predicted polling time
Child node 1	I_1	$P_1 = (P_1 + T)\%I_1$	$I_1 - P_1$
Child node 2	I_2	$P_2 = (P_2 + T)\%I_2$	$I_2 - P_2$
...	...	...	...
Child node n	I_n	$P_n = (P_n + T)\%I_n$	$I_n - P_n$
Parent's MAC Enable time	$T = \min(I_i - P_i)$		

[Fig. 7]