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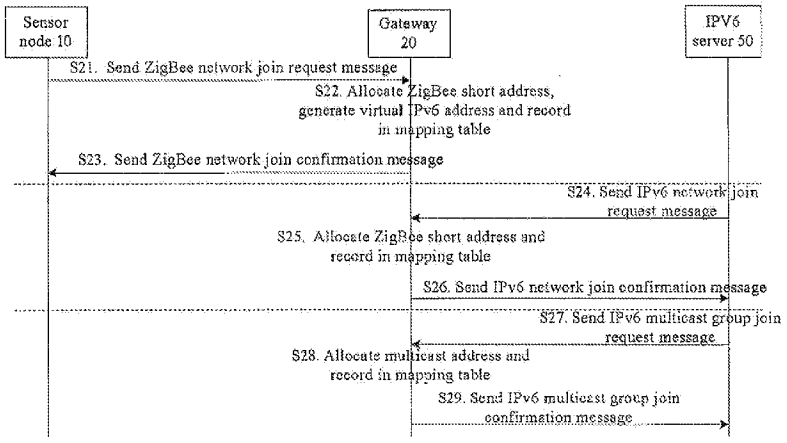


Fig.2

(57) Abstract: The invention provides a solution to interconnection and internetworking of a Zig Bee network and an IPv6 network to thereby achieve end-to-end communication over the sensor network. In a network join procedure, a gateway in the sensor network allocates a globally unique virtual IPv6 address for each sensor node and a Zig Bee short address for each IPv6 server in communication with the sensor node. Thus the sensor node is equivalent to a normal IPv6 node from the perspective of the server in the IPv6 network, and the IPv6 server is equivalent to a normal sensor node in the same sensor network from the perspective of the sensor node in the sensor network.

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# End-to-End Communication in Sensor Network

## Field of the invention

The present disclosure relates to a sensor network and particularly to end-to-end communication in a sensor network.

## Background of the invention

Sensor networks are widely used in numerous industrial or civilian applications. Currently the majority of the sensor networks are based on the ZigBee protocol to provide low-cost, low-power-consumption and bidirectional communication.

Since the TCP/IP protocol has become a dominant protocol over the Internet, interconnection of ZigBee networks based on the TCP/IP protocol is inevitable. Moreover since there are numerous problems occurring in the IPv4 (e.g., a shortage of IPv4 addresses), the IPv6 is a de factor networking standard for internetworking of ZigBee networks. However since the fundamental design of the ZigBee protocol is incompatible with the TCP/IP protocol, it is not easy to provide internetworking between them. For example, a ZigBee network is severely resource-constrained and capability-limited because sensor nodes in the ZigBee network have a short battery lifetime, a small form factor and a cost constraint, all of which restrain a memory space and a CPU speed and complicate a radio interface. Due to these constraints, the sensor nodes in the ZigBee network cannot perform IPv6 functions as a server in an IPv6 network does.

## Summary of the invention

In view of the foregoing drawbacks, it is advantageous to provide a new internetworking solution between a ZigBee network and an IPv6 network to thereby provide end-to-end communication in the sensor

network.

In order to provide end-to-end communication between a server of the IPv6 network and sensor nodes of the sensor network, a gateway in the sensor network allocates a globally unique virtual IPv6 address for each sensor node in a network join procedure, and the virtual IPv6 address is generated from an MAC address of the sensor node and an IPv6 network prefix of the gateway, for example, the virtual IPv6 address can be a 128-bit address which is generated as a result of combining the 64-bit MAC address of the sensor node and the 64-bit IPv6 network prefix of the gateway.

Since each sensor node is allocated a virtual IPv6 address, the sensor node is equivalent to a normal IPv6 node from the perspective of the server in the IPv6 network.

In order to provide end-to-end communication between the sensor nodes of the sensor network and the server of the IPv6 network, the gateway in the sensor network allocates a ZigBee short address, e.g., a 16-bit ZigBee short address, for each IPv6 server expecting communication with the sensor nodes in a network join procedure. The ZigBee short address is unique throughout the sensor network.

Since the IPv6 server is allocated with a ZigBee short address, the IPv6 server is equivalent to a normal sensor node from the perspective of the sensor nodes in the sensor network.

According to an aspect of the invention, there is provided a method, in a server of an IPv6 network, of joining a sensor network, the method including the steps of: sending an IPv6 network join request message to a gateway of the sensor network, the IPv6 network join request message including network identification information of the sensor network to be joined by the server and tag information indicating that the server is a terminal node; and receiving an IPv6 network join confirmation message from the gateway, the IPv6 network join confirmation message including a ZigBee short address allocated by the gateway for the server.

According to another aspect of the invention, there is provided a method, in a gateway of a sensor network, of assisting a server in an IPv6 network in joining the sensor network, the method including the steps of: receiving an IPv6 network join request message from the server, the IPv6 network join request message including network identification information of the sensor network to be joined by the server and tag information indicating that the server is a terminal node; allocating a ZigBee short address for the server and recording an IPv6 address of the server, the network identification information of the sensor network to be joined by the server and the ZigBee short address allocated for the server; and sending an IPv6 network join confirmation message to the server, the IPv6 network join confirmation message including the ZigBee short address allocated for the server.

According to another aspect of the invention, there is provided a method, in a gateway of a sensor network, of assisting a sensor node in joining the sensor network, the method including the steps of: receiving a ZigBee network join request message from the sensor node, the ZigBee network join request message including node identification information of the sensor node and network identification information of the sensor network to be joined by the sensor node; allocating a ZigBee short address for the sensor node, generating a virtual IPv6 address for the sensor node based upon an MAC address of the sensor node and an IPv6 network prefix of the gateway, and recording the node identification information of the sensor node, the network identification information of the sensor network to be joined by the sensor node, the ZigBee short address allocated for the sensor node and the virtual IPv6 address generated for the sensor node; and sending a ZigBee network join confirmation message to the sensor node, the ZigBee network join confirmation message including the ZigBee short address allocated for the sensor node.

According to another aspect of the invention, there is provided a method, in a sensor node of a sensor network, of data transmission with a

server in an IPv6 network, the sensor node and the server having joined the sensor network, wherein the method includes the steps of: sending a ZigBee data request message to a gateway in the sensor network, the ZigBee data request message including service identification information of data to be transmitted by the sensor node; receiving a ZigBee data confirmation message from the gateway, the ZigBee data confirmation message including a ZigBee short address of the server to indicate a destination of the data to be transmitted by the sensor node; and sending the ZigBee data to the gateway, a destination address of the ZigBee data being the ZigBee short address of the server.

According to another aspect of the invention, there is provided a method, in a server of an IPv6 network, of cooperating with a sensor node in a sensor network in data transmission, the server and the sensor node having joined the sensor network, wherein the method includes the steps of: receiving an IPv6 data request message from a gateway of the sensor network, the IPv6 data request message including service identification information of data to be transmitted by the sensor node; sending an IPv6 data confirmation message to the gateway upon determining from the service identification information that the data to be transmitted by the sensor node is the data that the server expects; and receiving IPv6 data from the gateway, a source address of the IPv6 data being a virtual IPv6 address of the sensor node.

According to another aspect of the invention, there is provided a method, in a gateway of a sensor network, of assisting a sensor node in the sensor network in data transmission with a server in an IPv6 network, the sensor node and the server having joined the sensor network, wherein the method includes the steps of: receiving a ZigBee data request message from the sensor node, the ZigBee data request message including service identification information of data to be transmitted by the sensor node; replacing a ZigBee network layer header of the ZigBee data request message with an IPv6 header to generate an IPv6 data request message;

sending the IPv6 data request message to the server, the IPv6 data request message including the service identification information of the data to be transmitted by the sensor node; receiving an IPv6 data confirmation message from the server; replacing an IPv6 header of the IPv6 data confirmation message with a ZigBee network layer header to generate a ZigBee data confirmation message and adding a ZigBee short address of the server to the ZigBee data confirmation message to indicate that the server is a destination of the data to be transmitted by the sensor node; sending the ZigBee data confirmation message to the sensor node, the ZigBee data confirmation message including the ZigBee short address of the server; receiving ZigBee data from the sensor node, a destination address of the ZigBee data being the ZigBee short address of the server; replacing a ZigBee network layer header of the ZigBee data with an IPv6 header to generate IPv6 data; and sending the IPv6 data to the server, a source address of the IPv6 data being a virtual IPv6 address of the sensor node.

According to another aspect of the invention, there is provided a method, in a server of an IPv6 network, of data transmission with a sensor node in a sensor network, the server and the sensor node having joined the sensor network, wherein the method includes the steps of: sending an IPv6 service discovery request message to a gateway of the sensor network, the IPv6 service discovery request message including service identification information of a service of interest to the server; receiving an IPv6 service discovery confirmation message from the gateway, the IPv6 service discovery confirmation message including a virtual IPv6 address of the sensor node to indicate that the sensor node can provide the service of interest to the server; and sending IPv6 data to the gateway, a destination address of the IPv6 data being the virtual IPv6 address of the sensor node.

According to another aspect of the invention, there is provided a method, in a sensor node of a sensor network, of cooperating with a server

in an IPv6 network in data transmission, the sensor node and the server having joined the sensor network, wherein the method includes the steps of: receiving a ZigBee service discovery request message from a gateway of the sensor network, the ZigBee service discovery request message including service identification information of a service of interest to the server; sending a ZigBee service discovery confirmation message to the gateway upon determining from the service identification information that the sensor node provides the service of interest to the server; and receiving ZigBee data from the gateway, a source address of the ZigBee data being a ZigBee short address of the server.

According to another aspect of the invention, there is provided a method, in a gateway of a sensor network, of assisting a server in an IPv6 network in data transmission with a sensor node in the sensor network, the server and the sensor node having joined the sensor network, wherein the method includes the steps of: receiving an IPv6 service discovery request message from the server, the IPv6 service discovery request message including service identification information of a service of interest to the server; replacing an IPv6 header of the IPv6 service discovery request message with a ZigBee network layer header to generate a ZigBee service discovery request message; sending the ZigBee service discovery request message to the sensor node, the ZigBee service discovery request message including the service identification information of the service of interest to the server; receiving a ZigBee service discovery confirmation message from the sensor node; replacing a ZigBee network layer header of the ZigBee service discovery confirmation message with an IPv6 header to generate an IPv6 service discovery confirmation message and adding a virtual IPv6 address of the sensor node to the IPv6 service discovery confirmation message to indicate that the sensor node can provide the service of interest to the server; sending the IPv6 service discovery confirmation message to the server, the IPv6 service discovery confirmation message including the virtual IPv6 address of the sensor

node; receiving IPv6 data from the server, a destination address of the IPv6 data being the virtual IPv6 address of the sensor node; replacing an IPv6 header of the IPv6 data with a ZigBee network layer header to generate ZigBee data; and sending the ZigBee data to the sensor node, a source address of the ZigBee data being a ZigBee short address of the server.

According to another aspect of the invention, there is provided a method, in a first sensor node of a first sensor network, of data transmission with a second sensor node in a second sensor network, the method including the steps of: sending a ZigBee service discovery request message to a first gateway of the first sensor network, the ZigBee service discovery request message including service identification information of an interested service of the first sensor node; receiving a ZigBee service discovery confirmation message from the first gateway, the ZigBee service discovery confirmation message including a ZigBee short address of the second sensor node in the second sensor network to indicate that the second sensor node can provide the interested service of the first sensor node in the first sensor network; receiving a ZigBee network rejoin indication message from the first gateway, the ZigBee network rejoin indication message including network identification information of the second sensor network to indicate a sensor network to be rejoined by the first sensor node; sending a ZigBee network rejoin request message to the first gateway, the ZigBee network rejoin request message including the network identification information of the second sensor network to indicate the sensor network to be rejoined by the first sensor node; receiving a ZigBee network rejoin confirmation message from the first gateway, the ZigBee network rejoin confirmation message including a ZigBee short address of the first sensor node in the second sensor network; and sending ZigBee data to the first gateway, a source address of the ZigBee data being the ZigBee short address of the first sensor node in the second sensor network.

According to another aspect of the invention, there is provided a method, in a first gateway of a first sensor network, of assisting a first sensor node in the first sensor network in data transmission with a second sensor node in a second sensor network, the method including the steps of: receiving a ZigBee service discovery request message from the first sensor node, the ZigBee service discovery request message including service identification information of a service of interest to the first sensor node; replacing a ZigBee network layer header of the ZigBee service discovery request message with an IPv6 header to generate an IPv6 service discovery request message; sending the IPv6 service discovery request message to a second gateway in the second sensor network, the IPv6 service discovery request message including the service identification information of the service of interest to the first sensor node; receiving an IPv6 service discovery confirmation message from the second gateway, the IPv6 service discovery confirmation message including network identification information of the second sensor network, a ZigBee short address of the second sensor node in the second sensor network and a virtual IPv6 address of the second sensor node to indicate that the second sensor node in the second sensor network provides the service of interest to the first sensor node, and recording the ZigBee short address of the second sensor node in the second sensor network and the virtual IPv6 address of the second sensor node; replacing an IPv6 header of the IPv6 service discovery confirmation message with a ZigBee network layer header to generate a ZigBee service discovery confirmation message; sending the ZigBee service discovery confirmation message to the first sensor node, the ZigBee service discovery confirmation message including the ZigBee short address of the second sensor node in the second sensor network to indicate that the second sensor node provides the service of interest to the first sensor node; sending a ZigBee network rejoin indication message to the first sensor node, the ZigBee network rejoin indication message including the network identification

information of the second sensor network to indicate a sensor network to be rejoined by the first sensor node; receiving a ZigBee network rejoin request message from the first sensor node, the ZigBee network rejoin request message including the network identification information of the second sensor network to indicate the sensor network to be rejoined by the first sensor node; replacing a ZigBee network layer header of the ZigBee network rejoin request message with an IPv6 header to generate an IPv6 network rejoin request message; sending the IPv6 network rejoin request message to the second gateway in the second sensor network, the IPv6 network rejoin request message including node identification information of the first sensor node, a virtual IPv6 address of the first sensor node, the network identification information of the sensor network to be rejoined by the first sensor node and tag information indicating that the first gateway is a gateway; receiving an IPv6 network rejoin confirmation message from the second gateway, the IPv6 network rejoin confirmation message including a ZigBee short address of the first sensor node in the second sensor network, and recording the ZigBee short address of the first sensor node in the second sensor network; replacing an IPv6 header of the IPv6 network rejoin confirmation message with a ZigBee network layer header to generate a ZigBee network rejoin confirmation message; sending the ZigBee network rejoin confirmation message to the first sensor node, the ZigBee network rejoin confirmation message including the ZigBee short address of the first sensor node in the second sensor network; receiving ZigBee data from the first sensor node, a source address of the ZigBee data being the ZigBee short address of the first sensor node in the second sensor network; replacing a ZigBee network layer header of the ZigBee data with an IPv6 header to generate IPv6 data; and sending the IPv6 data to the second gateway, a source address of the IPv6 data being the virtual IPv6 address of the first sensor node, and a destination address of the IPv6 data being the virtual IPv6 address of the second sensor node.

According to another aspect of the invention, there is provided a

method, in a second sensor node of a second sensor network, of cooperating with a first sensor node of a first sensor network in data transmission, the method including the steps of: receiving a ZigBee service discovery request message from a second gateway in the second sensor network, the ZigBee service discovery request message including service identification information of a service of interest to the first sensor node; sending a ZigBee service discovery confirmation message to the second gateway upon determining from the service identification information that the second sensor node provides the service of interest to the first sensor node; and receiving ZigBee data from the second gateway, a source address of the ZigBee data being a ZigBee short address of the first sensor node in the second sensor network.

According to another aspect of the invention, there is provided a method, in a second gateway of a second sensor network, of assisting a first sensor node in a first sensor network in data transmission with a second sensor node in the second sensor network, the method including the steps of: receiving an IPv6 service discovery request message from a first gateway in the first sensor network, the IPv6 service discovery request message including service identification information of a service of interest to the first sensor node; replacing an IPv6 header of the IPv6 service discovery request message with a ZigBee network layer header to generate a ZigBee service discovery request message; sending the ZigBee service discovery request message to the second sensor node, the ZigBee service discovery request message including the service identification information of the service of interest to the first sensor node; receiving a ZigBee service discover confirmation message from the second sensor node; replacing a ZigBee network layer header of the ZigBee service discover confirmation message with an IPv6 header to generate an IPv6 service discover confirmation message; sending the IPv6 service discover confirmation message to the first gateway in the first sensor network, the IPv6 service discover confirmation message including network

identification information of the second sensor network, a ZigBee short address of the second sensor node in the second sensor network and a virtual IPv6 address of the second sensor node to indicate that the second sensor node in the second sensor network provides the service of interest to the first sensor node; receiving an IPv6 network rejoin request message from the first gateway, the IPv6 network rejoin request message including node identification information of the first sensor node, a virtual IPv6 address of the first sensor node, network identification information of a sensor network to be rejoined by the first sensor node and tag information indicating that the first gateway is a gateway; allocating for the first sensor node a ZigBee short address thereof in the second sensor network and recording the virtual IPv6 address of the first sensor node and the ZigBee short address of the first sensor node in the second sensor network; sending an IPv6 network rejoin confirmation message to the first gateway, the IPv6 network rejoin confirmation message including the ZigBee short address of the first sensor node in the second sensor network; receiving IPv6 data from the first gateway, a source address of the IPv6 data being the virtual IPv6 address of the first sensor node, and a destination address of the IPv6 data being the virtual IPv6 address of the second sensor node; replacing an IPv6 header of the IPv6 data with a ZigBee network layer header to generate ZigBee data; and sending the ZigBee data to the second sensor node, a source address of the ZigBee data being the ZigBee short address of the first sensor node in the second sensor network.

Advantages of the invention lie in that:

- An IPv6 header is replaced with a ZigBee network layer header when a data packet is transmitted over a ZigBee network. Thus the data packet will suffer no problem with its size and have a sufficient room to bear application data;

- All of existing routing, addressing and data relaying solutions in the ZigBee network can be reused because the ZigBee network layer header is reserved;

- An important end-to-end mode is reserved in a communication process, e.g., information security; and

- End-to-end communication across different ZigBee networks is supported.

The respective aspects of the invention will become more apparent from the foregoing description of particular embodiments.

## Brief description of drawings

The foregoing and other features of the invention will become more apparent upon review of the following detailed description of non-limiting embodiments thereof with reference to the drawings in which:

Fig.1 illustrates a network architectural diagram of end-to-end communication over sensor networks according to an embodiment of the invention;

Fig.2 illustrates a flow chart of a method in which a sensor node and an IPv6 server join a sensor network according to an embodiment of the invention;

Fig.3(a) illustrates a mapping table about sensor nodes stored in a gateway according to an embodiment of the invention;

Fig.3(b) illustrates a mapping table about IPv6 servers stored in a gateway according to an embodiment of the invention;

Fig.4 illustrates a flow chart of a method of transmitting data from a ZigBee network to an IPv6 network according to an embodiment of the invention;

Fig.5 illustrates a flow chart of a method of transmitting data from an IPv6 network to a ZigBee network according to an embodiment of the invention; and

Fig.6 illustrates a flow chart of a method of transmitting data across different ZigBee networks according to an embodiment of the invention.

Identical or like reference numerals denote identical or like components throughout the drawings.

## Detailed description of embodiments

Fig.1 is a network architectural diagram of end-to-end communication over sensor networks according to an embodiment of the invention. In the figure where a sensor network A, a sensor network B and an IPv6 network are illustrated, a sensor node 10 and a gateway 20 are located in the sensor network A, a sensor node 30 and a gateway 40 are located in the sensor network B, and an IPv6 server 50 is located in the IPv6 network. The sensor network 10 is connected to the IPv6 network through the gateway 20, and the sensor node 30 is connected to the IPv6 network through the gateway 40.

It shall be noted that although only one sensor node is illustrated respectively in both the sensor network A and the sensor network B, a plurality of sensor nodes can be included respectively in both the sensor network A and the sensor network B in a practical application.

A flow of a method in which the sensor node 10 and the IPv6 server 50 join the sensor network A will be described below with reference to Fig.2 in combination with Fig.1 taking the sensor network A as an example.

The sensor node 10 joins the sensor network A.

Referring to Fig.2, first in the step S21, the sensor node 10 sends a ZigBee network join request message to the gateway 20. The ZigBee network join request message includes node identification information of the sensor node 10 and network identification information of a sensor network to be joined by the sensor node 10 (i.e., network identification information of the sensor network A).

After the gateway 20 receives the ZigBee network join request message from the sensor node 10, in the step S22, the gateway 20 allocates a ZigBee short address for the sensor node 10, generates an virtual IPv6 address for the sensor node 10 based upon an MAC address of the sensor node 10 and an IPv6 network prefix of the gateway 20 and records the identification information of the sensor node 10, the network

identification information of the sensor network to be joined by the sensor node 10 (i.e., the network identification information of the sensor network A), the ZigBee short address allocated for the sensor node 10 and the virtual IPv6 address generated for the sensor node 10.

For example, the gateway 20 can record the identification information of the sensor node 10, the network identification information of the sensor network to be joined by the sensor node 10, the ZigBee short address allocated for the sensor node 10 and the virtual IPv6 address generated for the sensor node 10 in a mapping table as illustrated in Fig.3(a).

Then in the step S23, the gateway 20 sends a ZigBee network join confirmation message to the sensor node 10. The ZigBee network join confirmation message includes the ZigBee short address allocated for the sensor node 10.

The IPv6 server 50 joins the sensor network A.

Referring to Fig.2, first in the step S24, the IPv6 server 50 sends an IPv6 network join request message to the gateway 20. The IPv6 network join request message includes network identification information of a sensor network to be joined by the IPv6 server 50 (i.e., network identification information of the sensor network A) and tag information indicating that the IPv6 server is a terminal node.

After the gateway 20 receives the IPv6 network join request message from the IPv6 server 50, in the step S25, the gateway 20 allocates a ZigBee short address for the IPv6 server 50 and records an IPv6 address of the IPv6 server 50, the network identification information of the sensor network to be joined by the IPv6 server 50 (i.e., the network identification information of the sensor network A) and the ZigBee short address allocated for the IPv6 server 50.

For example, the gateway 20 can record the IPv6 address of the IPv6 server 50, the network identification information of the sensor network to be joined by the IPv6 server 50 and the ZigBee short address allocated for the IPv6 server 50 in a mapping table as illustrated in Fig.3(b).

Then in the step S26, the gateway 20 sends an IPv6 network join confirmation message to the IPv6 server 50. The IPv6 network join confirmation message includes the ZigBee short address allocated for the IPv6 server.

The IPv6 server 50 joins a multicast group.

A multicast group can be created between the gateway 20 and the IPv6 server 50 in order to reduce the amount of data to be transmitted.

Referring to Fig.2, first in the step S27, the IPv6 server 50 sends an IPv6 multicast group join request message to the gateway 20. The IPv6 multicast group join request message includes group identification information of a multicast group to be joined by the IPv6 server 50.

After the gateway 20 receives the IPv6 multicast group join request message from the IPv6 server 50, in the step S28, the gateway 20 allocates a multicast address for the multicast group and records the group identification information and the multicast address of the multicast group. For example, the gateway 20 can record the group identification information and the multicast address of the multicast group in the mapping table as illustrated in Fig.3(b).

Then in the step S29, the gateway 20 sends an IPv6 multicast group join confirmation message to the IPv6 server 50. The IPv6 multicast group join confirmation message includes the allocated multicast address.

A flow of a method of transmitting data from a ZigBee network to an IPv6 network will be described below with reference to Fig.4 in combination with Fig.1 taking the sensor network A as an example.

Assumed that after the network join procedure, the sensor node 10 in the sensor gateway A expects communication with the IPv6 server 50 in the IPv6 network, for example, the sensor node 10 expects to send data sensed by the sensor node 10 to a destination interested in the data.

Referring to Fig.4, first in the step S41, the sensor node 10 sends a ZigBee data request message to the gateway 20, for example, the sensor node 10 can broadcast the ZigBee data request message over the sensor

network A. The ZigBee data request message includes service identification information of data to be sent by the sensor node 10.

After the gateway 20 receives the ZigBee data request message from the sensor node 10, in the step S42, the gateway 20 replaces a ZigBee network layer header of the ZigBee data request message with an IPv6 header to generate an IPv6 data request message.

Then in the step S43, the gateway 20 sends the IPv6 data request message to the IPv6 server 50, for example, the gateway 20 can send the IPv6 data request message in a multicast mode. The IPv6 data request message includes the service identification information of the data to be sent by the sensor node 10.

After the IPv6 server 50 receives the IPv6 data request message from the gateway 20, in the step S44, the IPv6 server 50 sends an IPv6 data confirmation message to the gateway 20 after the IPv6 server 50 determines from the service identification information in the IPv6 data request message that the data to be sent by the sensor node 10 is the data that the server expects. For example, the IPv6 server 50 can send the IPv6 data confirmation message to the gateway 20 in a unicast mode.

After the gateway 20 receives the IPv6 data confirmation message from the IPv6 server 50, in the step S45, the gateway 20 replaces an IPv6 header of the IPv6 data confirmation message with a ZigBee network layer header to generate a ZigBee data confirmation message and adds a ZigBee short address of the IPv6 server 50 to the ZigBee data confirmation message to indicate that the IPv6 server 50 is a destination of the data to be sent by the sensor node 10.

Then in the step S46, the gateway 20 sends the ZigBee data confirmation message to the sensor node 10, for example, the gateway 20 can send the ZigBee data confirmation message to the sensor node 10 in a unicast mode. The ZigBee data confirmation message includes the ZigBee short address of the IPv6 server 50.

So far the sensor node 10 can communicate directly with the IPv6

server 50. In communication, the sensor node 10 takes the IPv6 server 50 as a sensor node in the sensor network A, and the IPv6 server 50 takes the sensor node 10 as an IPv6 node.

Specifically, referring to Fig.4, in the step S47, the sensor node 10 sends ZigBee data to the gateway 20, a destination address of the ZigBee data being a ZigBee short address of the IPv6 server 50.

After the gateway 20 receives the ZigBee data from the sensor node 10, in the step S48, the gateway 20 replaces a ZigBee network layer header of the ZigBee data with an IPv6 header to generate IPv6 data.

Then in the step S49, the gateway 20 sends the IPv6 data to the IPv6 server 50, a source address of the IPv6 data being a virtual IPv6 address of the sensor node 10.

A flow of a method of transmitting data from an IPv6 network to a ZigBee network will be described below with reference to Fig.5 in combination with Fig.1 taking the sensor network A as an example.

Assumed that after the network join procedure, the IPv6 server 50 in the IPv6 network expects communication with the sensor node 10 in the sensor gateway A, for example, the IPv6 server 50 expects a service of interest.

Referring to Fig.5, first in the step S51, the IPv6 server 50 sends an IPv6 service discovery request message to the gateway 20, for example, the IPv6 server 50 can send the IPv6 service discovery request message to the gateway 20 in a multicast mode. The IPv6 service discovery request message includes service identification information of a service of interest to the IPv6 server 50 (i.e., a service in which the IPv6 server 50 is interested).

After the gateway 20 receives the IPv6 service discovery request message from the IPv6 server 50, in the step S52, the gateway 20 replaces an IPv6 header of the IPv6 service discovery request message with a ZigBee network layer header to generate a ZigBee service discovery request message.

Then in the step S53, the gateway 20 sends the ZigBee service discovery request message to the sensor node 10, for example, the gateway 20 can send the ZigBee service discovery request message in a broadcast mode. The ZigBee service discovery request message includes the service identification information of the service of interest to the IPv6 server 50.

After the sensor node 10 receives the ZigBee service discovery request message from the gateway 20, in the step S54, the sensor node 10 sends a ZigBee service discovery confirmation message to the gateway 20 after the sensor node 10 determines from the service identification information in the ZigBee service discovery request message that the sensor node provides the service of interest to the IPv6 server 50 (i.e., the service in which the IPv6 server 50 is interested). For example, the sensor node 10 can send the ZigBee service discovery confirmation message to the gateway 20 in a unicast mode.

After the gateway 20 receives the ZigBee service discovery confirmation message from the sensor node 10, in the step S55, the gateway 20 replaces a ZigBee network layer header of the ZigBee service discovery confirmation message with an IPv6 header to generate an IPv6 service discovery confirmation message and adds a virtual IPv6 address of the sensor node 10 to the IPv6 service discovery confirmation message to indicate that the sensor node 10 can provide the service of interest to the IPv6 server 50.

Then in the step S56, the gateway 20 sends the IPv6 service discovery confirmation message to the IPv6 server 50, for example, the gateway 20 can send the IPv6 service discovery confirmation message to the IPv6 server 50 in a unicast mode. The IPv6 service discovery confirmation message includes the virtual IPv6 address of the sensor node 10.

So far the IPv6 server 50 can communicate directly with the sensor node 10.

Specifically, referring to Fig.5, in the step S57, the IPv6 server 50

sends IPv6 data to the gateway 20, a destination address of the IPv6 data being the virtual IPv6 address of the sensor node 10.

After the gateway 20 receives the IPv6 data from the IPv6 server 50, in the step S58, the gateway 20 replaces an IPv6 header of the IPv6 data with a ZigBee network layer header to generate ZigBee data.

Then in the step S59, the gateway 20 sends the ZigBee data to the sensor node 10, a source address of the ZigBee data being a ZigBee short address of the IPv6 server 50.

A flow of a method of transmitting data across different ZigBee networks will be described below with reference to Fig.6 in combination with Fig.1.

Assumed that after the network join procedure, the sensor node 10 in the sensor network A expects communication with the sensor node 30 in the sensor network B, for example, the sensor node 10 expects a specific service.

Referring to Fig.6, first in the step S601, the sensor node 10 sends a ZigBee service discovery request message to the gateway 20, for example, the sensor node 10 can send the ZigBee service discovery request message in a broadcast mode. The ZigBee service discovery request message includes service identification information of a service of interest to the sensor node 10.

After the gateway 20 receives the ZigBee service discovery request message from the sensor node 10, in the step 602, the gateway 20 replaces a ZigBee network layer header of the ZigBee service discovery request message with an IPv6 header to generate an IPv6 service discovery request message.

Then in the step S603, the gateway 20 sends the IPv6 service discovery request message to the gateway 40 in the sensor network B, for example, the gateway 20 can send the IPv6 service discovery request message in a multicast mode. The IPv6 service discovery request message includes the service identification information of the service of interest to

the sensor node 10.

After the gateway 40 receives the IPv6 service discovery request message from the gateway 20 of the sensor network A, in the step S604, the gateway 40 replaces an IPv6 header of the IPv6 service discovery request message with a ZigBee network layer header to generate a ZigBee service discovery request message.

Then in the step S605, the gateway 40 sends the ZigBee service discovery request message to the sensor node 30, for example, the gateway 40 can send the ZigBee service discovery request message in a broadcast mode. The ZigBee service discovery request message includes the service identification information of the service of interest to the sensor node 10.

After the sensor node 30 receives the ZigBee service discovery request message from the gateway 40, in the step S606, the sensor nodes 30 sends a ZigBee service discovery confirmation message to the gateway 40 after the sensor node 30 determines from the service identification information in the ZigBee service discovery request message that the sensor node 30 provides the service of interest to the sensor node 10. For examples, the sensor node 30 can send the ZigBee service discovery confirmation message in a unicast mode.

After the gateway 40 receives the ZigBee service discovery confirmation message from the sensor node 30, in the step S607, the gateway 40 replaces a ZigBee network layer header of the ZigBee service discovery confirmation message with an IPv6 header to generate an IPv6 service discovery confirmation message.

Then in the step S608, the gateway 40 sends the IPv6 service discovery confirmation message to the gateway 20 in the sensor network A, for example, the gateway 40 can send the IPv6 service discovery confirmation message in a unicast mode. The IPv6 service discovery confirmation message includes network identification information of the sensor network B, a ZigBee short address of the sensor node 30 in the

sensor network B and a virtual IPv6 address of the sensor node 30 to indicate that the sensor node 30 in the sensor network B provides the service of interest to the sensor node 10.

After the gateway 20 receives the IPv6 service discovery confirmation message from the gateway 40, in the step S609, the gateway 20 records the ZigBee short address of the sensor node 30 in the sensor network B and the virtual IPv6 address of the sensor node 30 and replaces an IPv6 header of the IPv6 service discovery confirmation message with a ZigBee network layer header to generate a ZigBee service discovery confirmation message. For example, the gateway 20 can record the ZigBee short address of the sensor node 30 in the sensor network B and the virtual IPv6 address of the sensor node 30 in the mapping table as illustrated in Fig.3(a).

Then in the step S610, the gateway 20 sends the ZigBee service discovery confirmation message to the sensor node 10, for example, the gateway 20 can send the ZigBee service discovery confirmation message in a unicast mode. The ZigBee service discovery confirmation message includes the ZigBee short address of the sensor node 30 in the sensor network B to indicate that the sensor node 30 provides the service of interest to the sensor node 10.

Since the sensor node 30 is located in the sensor network B instead of the sensor network A, the sensor node 10 needs to obtain a ZigBee short address of the sensor node 10 in the sensor network B (because ZigBee short addresses of the sensor node in the different sensor networks may be different).

Still referring to Fig.6, first in the step S611, the gateway 20 sends a ZigBee network rejoin indication message to the sensor node 10. The ZigBee network rejoin indication message includes the network identification information of the sensor network B to indicate a sensor network to be rejoined by the sensor node 10.

After the sensor node 10 receives the ZigBee network rejoin indication

message from the gateway 20, in the step S612, the sensor node 10 sends a ZigBee network rejoin request message to the gateway 20. The ZigBee network rejoin request message includes the network identification information of the sensor network B to indicate the sensor network to be rejoined by the sensor node 10.

After the gateway 20 receives the ZigBee network rejoin request message from the sensor node 10, in the step S613, the gateway replaces a ZigBee network layer header of the ZigBee network rejoin request message with an IPv6 header to generate an IPv6 network rejoin request message.

Then in the step S614, the gateway 20 sends the IPv6 network rejoin request message to the gateway 40 in the sensor network B. The IPv6 network rejoin request message includes node identification information of the sensor node 10, a virtual IPv6 address of the sensor node 10, the network identification information of the sensor network to be rejoined by the sensor node 10 (i.e., the network identification information of the sensor network B) and tag information indicating that the gateway 20 is a gateway.

After the gateway 40 receives the IPv6 network rejoin request message from the gateway 20, in the step S615, the gateway 40 allocates for the sensor node 10 a ZigBee short address thereof in the sensor network B and records the virtual IPv6 address of the sensor node 10 and the ZigBee short address of the sensor node 10 in the sensor network B. For example, the gateway 40 can record the virtual IPv6 address of the sensor node 10 and the ZigBee short address of the sensor node 10 in the sensor network B in the mapping table as illustrated in Fig.3(a).

Then in the step S616, the gateway 40 sends an IPv6 network rejoin confirmation message to the gateway 20 in the sensor node A. The IPv6 network rejoin confirmation message includes the ZigBee short address of the sensor node 10 in the sensor network B.

After the gateway 20 receives the IPv6 network rejoin confirmation

message from the gateway 40, in the step S617, the gateway 20 records the ZigBee short address of the sensor node 10 in the sensor network B and replaces an IPv6 header of the IPv6 network rejoin confirmation message with a ZigBee network layer header to generate a ZigBee network rejoin confirmation message to the gateway 20 in the sensor network A. For example, the gateway 20 records the ZigBee short address of the sensor node 10 in the sensor network B in the mapping table as illustrated in Fig.3(a).

Then in the step S618, the gateway 20 sends the ZigBee network rejoin confirmation message to the sensor node 10. The ZigBee network rejoin confirmation message includes the ZigBee short address of the sensor node 10 in the sensor network B.

So far the sensor node 10 can communicate directly with the sensor node 30 in the sensor node B by using the ZigBee short address of the sensor node 10 in the sensor network B.

Specifically, referring to Fig.6, in the step S619, the sensor node 10 sends ZigBee data to the gateway 20. A source address of the ZigBee data is the ZigBee short address of the sensor node 10 in the sensor network B.

After the gateway 20 receives the ZigBee data from the sensor node 10, in the step S620, the gateway 20 replaces a ZigBee network layer header of the ZigBee data with an IPv6 header to generate IPv6 data.

Then in the step S621, the gateway 20 sends the IPv6 data to the gateway 40 in the sensor network B. A source address of the IPv6 data is the virtual IPv6 address of the sensor node 10, and a destination address of the IPv6 data is a virtual IPv6 address of the sensor node 30.

After the gateway 40 receives the IPv6 data from the gateway 20, in the step S622, the gateway 40 replaces an IPv6 header of the IPv6 data with a ZigBee network layer header to generate ZigBee data.

Then in the step S623, the gateway 40 sends the ZigBee data to the sensor ndoe 30. A source address of the ZigBee data is the ZigBee short address of the sensor node 10 in the sensor network B.

Those skilled in the art shall appreciate that the invention apparently will not be limited to the foregoing exemplary embodiments and can be embodied in other particular forms without departing from the spirit or essence of the invention. Accordingly the embodiments shall be construed anyway to be exemplary and non-limiting, and any reference numerals in the claims shall not be taken as limiting the claims in which they appear. Moreover apparently the term "comprising" will not preclude another element(s) or step(s), and the term "a" or "an" preceding an element will not preclude a plurality of such elements. A plurality of elements stated in an apparatus claim can alternatively be embodied as a single element in software or hardware. The terms "first", "second", etc., are intended to designate a name but not to suggest any specific order.

# CLAIMS

1. A method, in a server of an IPv6 network, of joining a sensor network, the method comprising the steps of:

- sending an IPv6 network join request message to a gateway of the sensor network, the IPv6 network join request message including network identification information of the sensor network to be joined by the server and tag information indicating that the server is a terminal node; and

- receiving an IPv6 network join confirmation message from the gateway, the IPv6 network join confirmation message including a ZigBee short address allocated by the gateway for the server.

2. A method, in a gateway of a sensor network, of assisting a server in an IPv6 network in joining the sensor network, the method comprising the steps of:

- receiving an IPv6 network join request message from the server, the IPv6 network join request message including network identification information of the sensor network to be joined by the server and tag information indicating that the server is a terminal node;

- allocating a ZigBee short address for the server and recording an IPv6 address of the server, the network identification information of the sensor network to be joined by the server and the ZigBee short address allocated for the server; and

- sending an IPv6 network join confirmation message to the server, the IPv6 network join confirmation message including the ZigBee short address allocated for the server.

3. A method, in a gateway of a sensor network, of assisting a sensor node in joining the sensor network, the method comprising the steps of:

- receiving a ZigBee network join request message from the sensor node, the ZigBee network join request message including node identification information of the sensor node and network identification information of the sensor network to be joined by the sensor node;

- allocating a ZigBee short address for the sensor node, generating a virtual IPv6 address for the sensor node based upon an MAC address of the sensor node and an IPv6 network prefix of the gateway, and recording the node identification information of the sensor node, the network identification information of the sensor network to be joined by the sensor node, the ZigBee short address allocated for the sensor node and the virtual IPv6 address generated for the sensor node; and

- sending a ZigBee network join confirmation message to the sensor node, the ZigBee network join confirmation message including the ZigBee short address allocated for the sensor node.

4. A method, in a sensor node of a sensor network, of data transmission with a server in an IPv6 network, the sensor node and the server having joined the sensor network, wherein the method comprises the steps of:

- sending a ZigBee data request message to a gateway in the sensor network, the ZigBee data request message including service identification information of data to be transmitted by the sensor node;

- receiving a ZigBee data confirmation message from the gateway, the ZigBee data confirmation message including a ZigBee short address of the server to indicate a destination of the data to be transmitted by the sensor node; and

- sending the ZigBee data to the gateway, a destination address of the ZigBee data being the ZigBee short address of the server.

5. A method, in a server of an IPv6 network, of cooperating with a sensor node in a sensor network in data transmission, the server and the sensor node having joined the sensor network, wherein the method comprises the steps of:

- receiving an IPv6 data request message from a gateway of the sensor network, the IPv6 data request message including service identification information of data to be transmitted by the sensor node;

- sending an IPv6 data confirmation message to the gateway upon determining from the service identification information that the data to be

transmitted by the sensor node is the data that the server expects; and

- receiving IPv6 data from the gateway, a source address of the IPv6 data being a virtual IPv6 address of the sensor node.

6. A method, in a gateway of a sensor network, of assisting a sensor node in the sensor network in data transmission with a server in an IPv6 network, the sensor node and the server having joined the sensor network, wherein the method comprises the steps of:

- receiving a ZigBee data request message from the sensor node, the ZigBee data request message including service identification information of data to be transmitted by the sensor node;

- replacing a ZigBee network layer header of the ZigBee data request message with an IPv6 header to generate an IPv6 data request message;

- sending the IPv6 data request message to the server, the IPv6 data request message including the service identification information of the data to be transmitted by the sensor node;

- receiving an IPv6 data confirmation message from the server;

- replacing an IPv6 header of the IPv6 data confirmation message with a ZigBee network layer header to generate a ZigBee data confirmation message and adding a ZigBee short address of the server to the ZigBee data confirmation message to indicate that the server is a destination of the data to be transmitted by the sensor node;

- sending the ZigBee data confirmation message to the sensor node, the ZigBee data confirmation message including the ZigBee short address of the server;

- receiving ZigBee data from the sensor node, a destination address of the ZigBee data being the ZigBee short address of the server;

- replacing a ZigBee network layer header of the ZigBee data with an IPv6 header to generate IPv6 data; and

- sending the IPv6 data to the server, a source address of the IPv6 data being a virtual IPv6 address of the sensor node.

7. A method, in a server of an IPv6 network, of data transmission with a

sensor node in a sensor network, the server and the sensor node having joined the sensor network, wherein the method comprises the steps of:

- sending an IPv6 service discovery request message to a gateway of the sensor network, the IPv6 service discovery request message including service identification information of a service of interest to the server;

- receiving an IPv6 service discovery confirmation message from the gateway, the IPv6 service discovery confirmation message including a virtual IPv6 address of the sensor node to indicate that the sensor node can provide the service of interest to the server; and

- sending IPv6 data to the gateway, a destination address of the IPv6 data being the virtual IPv6 address of the sensor node.

8. A method, in a sensor node of a sensor network, of cooperating with a server in an IPv6 network in data transmission, the sensor node and the server having joined the sensor network, wherein the method comprises the steps of:

- receiving a ZigBee service discovery request message from a gateway of the sensor network, the ZigBee service discovery request message comprising service identification information of a service of interest to the server;

- sending a ZigBee service discovery confirmation message to the gateway upon determining from the service identification information that the sensor node provides the service of interest to the server; and

- receiving ZigBee data from the gateway, a source address of the ZigBee data being a ZigBee short address of the server.

9. A method, in a gateway of a sensor network, of assisting a server in an IPv6 network in data transmission with a sensor node in the sensor network, the server and the sensor node having joined the sensor network, wherein the method comprises the steps of:

- receiving an IPv6 service discovery request message from the server, the IPv6 service discovery request message including service identification information of a service of interest to the server;

- replacing an IPv6 header of the IPv6 service discovery request message with a ZigBee network layer header to generate a ZigBee service discovery request message;

- sending the ZigBee service discovery request message to the sensor node, the ZigBee service discovery request message including the service identification information of the service of interest to the server;

- receiving a ZigBee service discovery confirmation message from the sensor node;

- replacing a ZigBee network layer header of the ZigBee service discovery confirmation message with an IPv6 header to generate an IPv6 service discovery confirmation message and adding a virtual IPv6 address of the sensor node to the IPv6 service discovery confirmation message to indicate that the sensor node can provide the service of interest to the server;

- sending the IPv6 service discovery confirmation message to the server, the IPv6 service discovery confirmation message including the virtual IPv6 address of the sensor node;

- receiving IPv6 data from the server, a destination address of the IPv6 data being the virtual IPv6 address of the sensor node;

- replacing an IPv6 header of the IPv6 data with a ZigBee network layer header to generate ZigBee data; and

- sending the ZigBee data to the sensor node, a source address of the ZigBee data being a ZigBee short address of the server.

10. A method, in a first sensor node of a first sensor network, of data transmission with a second sensor node in a second sensor network, the method comprising the steps of:

- sending a ZigBee service discovery request message to a first gateway of the first sensor network, the ZigBee service discovery request message including service identification information of a service of interest to the first sensor node;

- receiving a ZigBee service discovery confirmation message from the first gateway, the ZigBee service discovery confirmation message including a

ZigBee short address of the second sensor node in the second sensor network to indicate that the second sensor node can provide the service of interest to the first sensor node in the first sensor network;

- receiving a ZigBee network rejoin indication message from the first gateway, the ZigBee network rejoin indication message including network identification information of the second sensor network to indicate a sensor network to be rejoined by the first sensor node;

- sending a ZigBee network rejoin request message to the first gateway, the ZigBee network rejoin request message including the network identification information of the second sensor network to indicate the sensor network to be rejoined by the first sensor node;

- receiving a ZigBee network rejoin confirmation message from the first gateway, the ZigBee network rejoin confirmation message including a ZigBee short address of the first sensor node in the second sensor network; and

- sending ZigBee data to the first gateway, a source address of the ZigBee data being the ZigBee short address of the first sensor node in the second sensor network.

11. A method, in a first gateway of a first sensor network, of assisting a first sensor node in the first sensor network in data transmission with a second sensor node in a second sensor network, the method comprising the steps of:

- receiving a ZigBee service discovery request message from the first sensor node, the ZigBee service discovery request message including service identification information of a service of interest to the first sensor node;

- replacing a ZigBee network layer header of the ZigBee service discovery request message with an IPv6 header to generate an IPv6 service discovery request message;

- sending the IPv6 service discovery request message to a second gateway in the second sensor network, the IPv6 service discovery request message including the service identification information of the service of

interest to the first sensor node;

- receiving an IPv6 service discovery confirmation message from the second gateway, the IPv6 service discovery confirmation message including network identification information of the second sensor network, a ZigBee short address of the second sensor node in the second sensor network and a virtual IPv6 address of the second sensor node to indicate that the second sensor node in the second sensor network provides the service of interest to the first sensor node, and recording the ZigBee short address of the second sensor node in the second sensor network and the virtual IPv6 address of the second sensor node;

- replacing an IPv6 header of the IPv6 service discovery confirmation message with a ZigBee network layer header to generate a ZigBee service discovery confirmation message;

- sending the ZigBee service discovery confirmation message to the first sensor node, the ZigBee service discovery confirmation message including the ZigBee short address of the second sensor node in the second sensor network to indicate that the second sensor node provides the service of interest to the first sensor node;

- sending a ZigBee network rejoin indication message to the first sensor node, the ZigBee network rejoin indication message including the network identification information of the second sensor network to indicate a sensor network to be rejoined by the first sensor node;

- receiving a ZigBee network rejoin request message from the first sensor node, the ZigBee network rejoin request message including the network identification information of the second sensor network to indicate the sensor network to be rejoined by the first sensor node;

- replacing a ZigBee network layer header of the ZigBee network rejoin request message with an IPv6 header to generate an IPv6 network rejoin request message;

- sending the IPv6 network rejoin request message to the second gateway in the second sensor network, the IPv6 network rejoin request

message including node identification information of the first sensor node, a virtual IPv6 address of the first sensor node, the network identification information of the sensor network to be rejoined by the first sensor node and tag information indicating that the first gateway is a gateway;

- receiving an IPv6 network rejoin confirmation message from the second gateway, the IPv6 network rejoin confirmation message including a ZigBee short address of the first sensor node in the second sensor network, and recording the ZigBee short address of the first sensor node in the second sensor network;

- replacing an IPv6 header of the IPv6 network rejoin confirmation message with a ZigBee network layer header to generate a ZigBee network rejoin confirmation message;

- sending the ZigBee network rejoin confirmation message to the first sensor node, the ZigBee network rejoin confirmation message including the ZigBee short address of the first sensor node in the second sensor network;

- receiving ZigBee data from the first sensor node, a source address of the ZigBee data being the ZigBee short address of the first sensor node in the second sensor network;

- replacing a ZigBee network layer header of the ZigBee data with an IPv6 header to generate IPv6 data; and

- sending the IPv6 data to the second gateway, a source address of the IPv6 data being the virtual IPv6 address of the first sensor node, and a destination address of the IPv6 data being the virtual IPv6 address of the second sensor node.

12. A method, in a second sensor node of a second sensor network, of cooperating with a first sensor node of a first sensor network in data transmission, the method comprising the steps of:

- receiving a ZigBee service discovery request message from a second gateway in the second sensor network, the ZigBee service discovery request message including service identification information of a service of interest to the first sensor node;

- sending a ZigBee service discovery confirmation message to the second gateway upon determining from the service identification information that the second sensor node provides the ested service of interest to the first sensor node; and

- receiving ZigBee data from the second gateway, a source address of the ZigBee data being a ZigBee short address of the first sensor node in the second sensor network.

13. A method, in a second gateway of a second sensor network, of assisting a first sensor node in a first sensor network in data transmission with a second sensor node in the second sensor network, the method comprising the steps of:

- receiving an IPv6 service discovery request message from a first gateway in the first sensor network, the IPv6 service discovery request message including service identification information of a service of interest to the first sensor node;

- replacing an IPv6 header of the IPv6 service discovery request message with a ZigBee network layer header to generate a ZigBee service discovery request message;

- sending the ZigBee service discovery request message to the second sensor node, the ZigBee service discovery request message including the service identification information of the service of interest to the first sensor node;

- receiving a ZigBee service discover confirmation message from the second sensor node;

- replacing a ZigBee network layer header of the ZigBee service discover confirmation message with an IPv6 header to generate an IPv6 service discover confirmation message;

- sending the IPv6 service discover confirmation message to the first gateway in the first sensor network, the IPv6 service discover confirmation message including network identification information of the second sensor network, a ZigBee short address of the second sensor node in the second

sensor network and a virtual IPv6 address of the second sensor node to indicate that the second sensor node in the second sensor network provides the service of interest to the first sensor node;

- receiving an IPv6 network rejoin request message from the first gateway, the IPv6 network rejoin request message including node identification information of the first sensor node, a virtual IPv6 address of the first sensor node, network identification information of a sensor network to be rejoined by the first sensor node and tag information indicating that the first gateway is a gateway;

- allocating for the first sensor node a ZigBee short address thereof in the second sensor network and recording the virtual IPv6 address of the first sensor node and the ZigBee short address of the first sensor node in the second sensor network;

- sending an IPv6 network rejoin confirmation message to the first gateway, the IPv6 network rejoin confirmation message including the ZigBee short address of the first sensor node in the second sensor network;

- receiving IPv6 data from the first gateway, a source address of the IPv6 data being the virtual IPv6 address of the first sensor node, and a destination address of the IPv6 data being the virtual IPv6 address of the second sensor node;

- replacing an IPv6 header of the IPv6 data with a ZigBee network layer header to generate ZigBee data; and

- sending the ZigBee data to the second sensor node, a source address of the ZigBee data being the ZigBee short address of the first sensor node in the second sensor network.

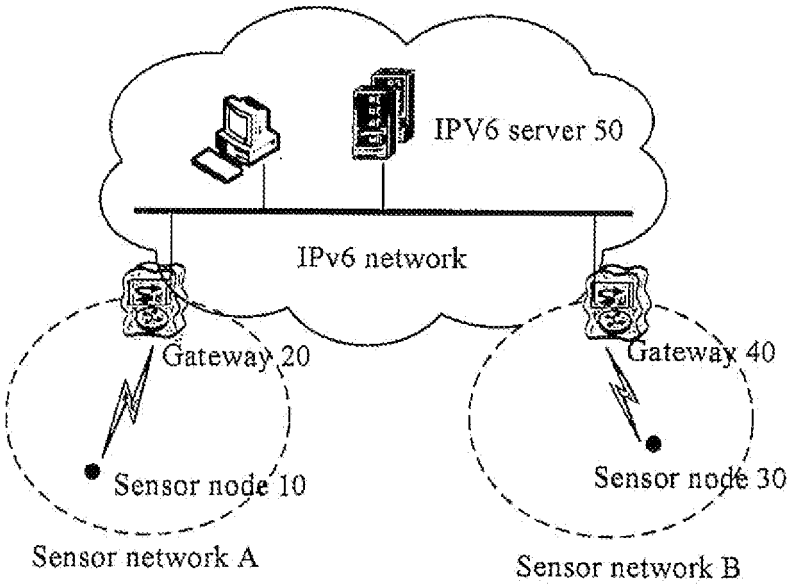
IPV6 server 50
IPv6 network
Gateway 20
Gateway 40
Sensor node 10
Sensor node 30
Sensor network A
Sensor network B

Fig. 1

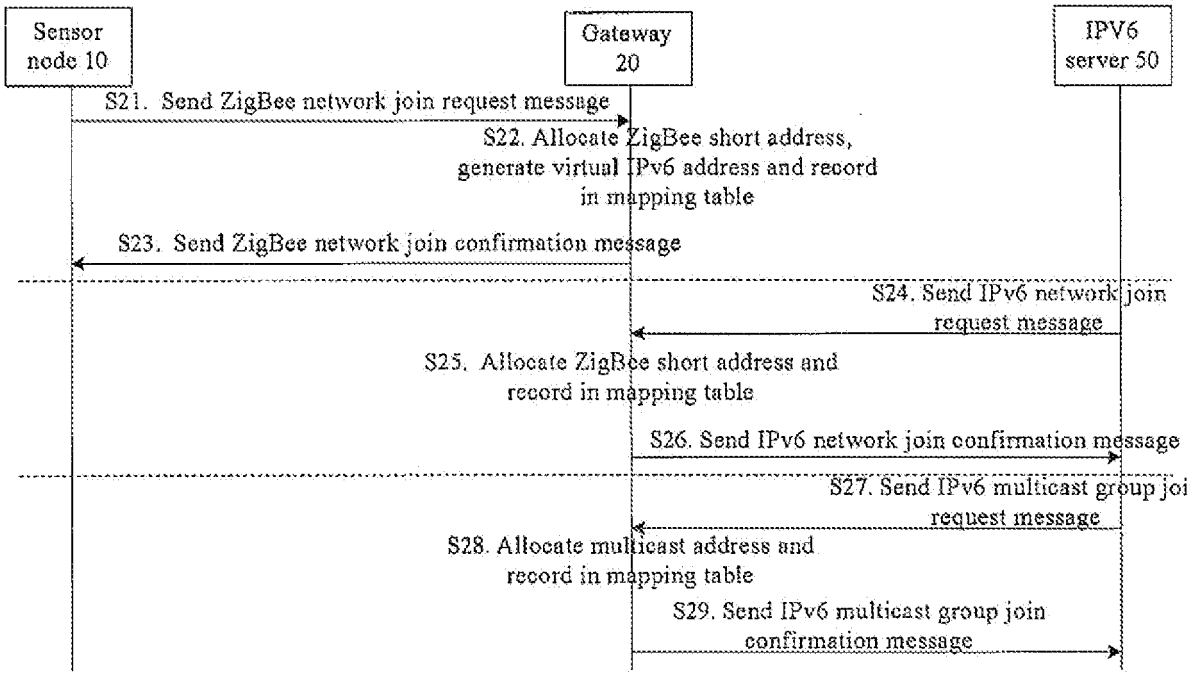
Sensor node 10
Gateway 20
IPV6 server 50
S21. Send ZigBee network join request message
S22. Allocate ZigBee short address, generate virtual IPv6 address and record in mapping table
S23. Send ZigBee network join confirmation message
S24. Send IPv6 network join request message
S25. Allocate ZigBee short address and record in mapping table
S26. Send IPv6 network join confirmation message
S27. Send IPv6 multicast group joi request message
S28. Allocate multicast address and record in mapping table
S29. Send IPv6 multicast group join confirmation message

Fig.2

| Node identification information of sensor node | Network identification information of sensor network | Virtual IPv6 address | ZigBee short address | Multicast group | |
|---|---|---|---|---|---|
| | | | | Multicast identification information | Multicast address |
| ... ... | ... ... | ... ... | ... ... | ... ... | ... ... |
| ... ... | ... ... | ... ... | ... ... | ... ... | ... ... |

Fig. 3(a)

| IPv6 address | Network identification information of sensor network | ZigBee short address | Multicast group | |
|---|---|---|---|---|
| | | | Multicast identification information | Multicast address |
| ... ... | ... ... | ... ... | ... ... | ... ... |
| ... ... | ... ... | ... ... | ... ... | ... ... |

Fig. 3(b)

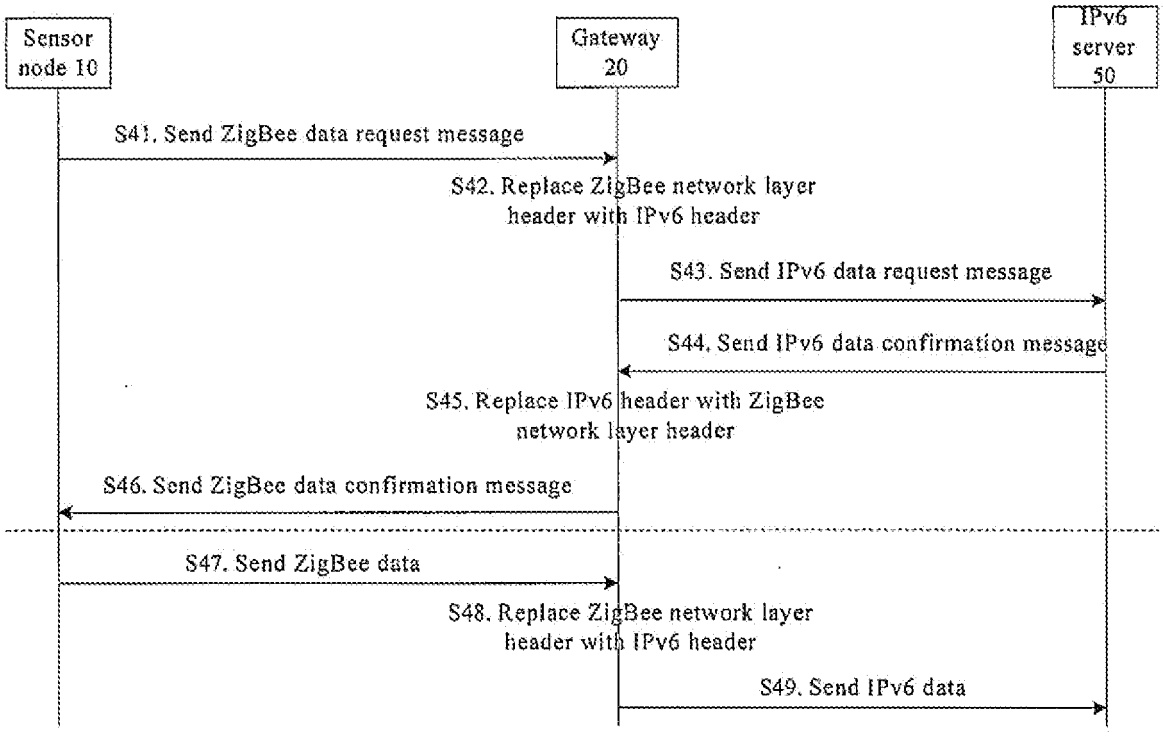
Sensor node 10
Gateway 20
IPv6 server 50
S41. Send ZigBee data request message
S42. Replace ZigBee network layer header with IPv6 header
S43. Send IPv6 data request message
S44. Send IPv6 data confirmation message
S45. Replace IPv6 header with ZigBee network layer header
S46. Send ZigBee data confirmation message
S47. Send ZigBee data
S48. Replace ZigBee network layer header with IPv6 header
S49. Send IPv6 data

Fig.4

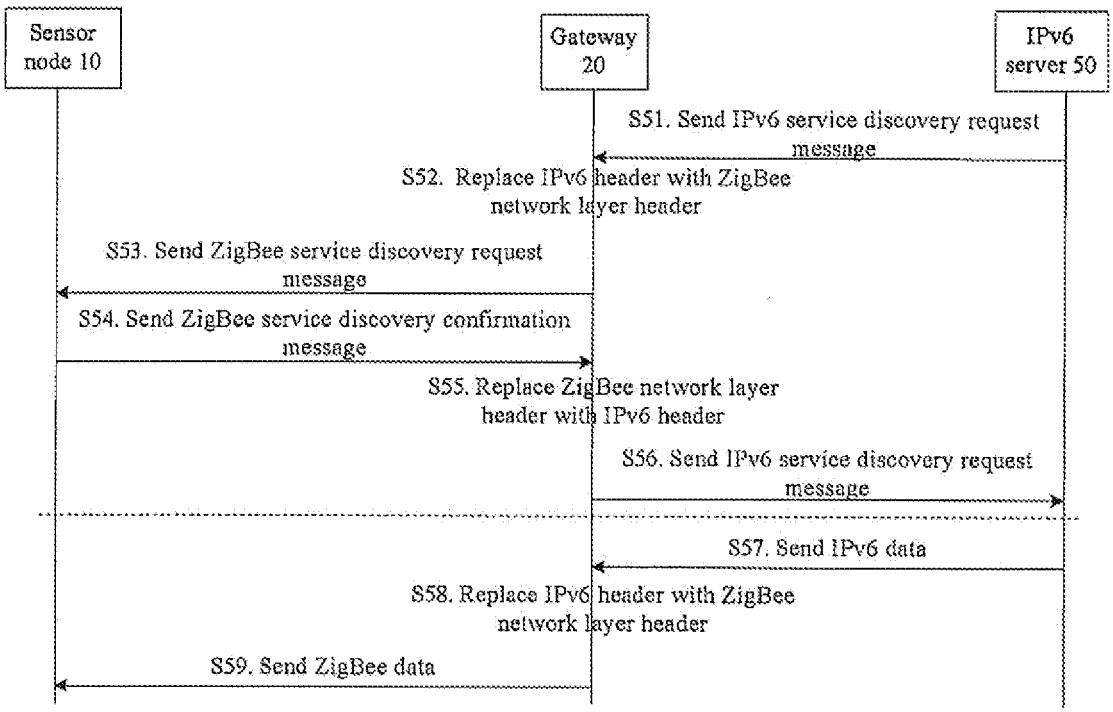
Sensor node 10
Gateway 20
IPv6 server 50
S51. Send IPv6 service discovery request message
S52. Replace IPv6 header with ZigBee network layer header
S53. Send ZigBee service discovery request message
S54. Send ZigBee service discovery confirmation message
S55. Replace ZigBee network layer header with IPv6 header
S56. Send IPv6 service discovery request message
S57. Send IPv6 data
S58. Replace IPv6 header with ZigBee network layer header
S59. Send ZigBee data

Fig.5

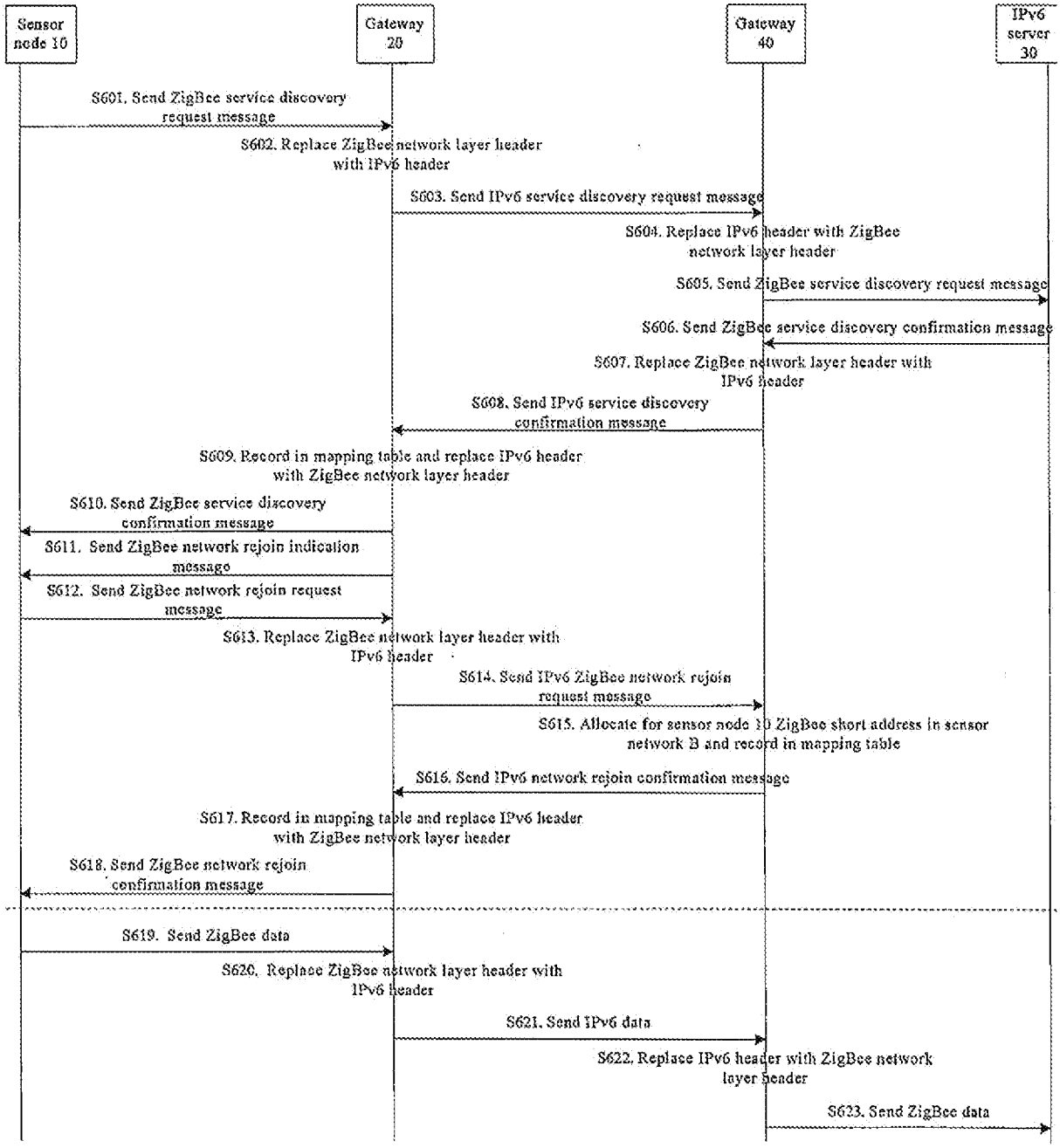
Sensor node 10
Gateway 20
Gateway 40
IPv6 server 30
S601. Send ZigBee service discovery request message
S602. Replace ZigBee network layer header with IPv6 header
S603. Send IPv6 service discovery request message
S604. Replace IPv6 header with ZigBee network layer header
S605. Send ZigBee service discovery request message
S606. Send ZigBee service discovery confirmation message
S607. Replace ZigBee network layer header with IPv6 header
S608. Send IPv6 service discovery confirmation message
S609. Record in mapping table and replace IPv6 header with ZigBee network layer header
S610. Send ZigBee service discovery confirmation message
S611. Send ZigBee network rejoin indication message
S612. Send ZigBee network rejoin request message
S613. Replace ZigBee network layer header with IPv6 header
S614. Send IPv6 ZigBee network rejoin request message
S615. Allocate for sensor node 10 ZigBee short address in sensor network B and record in mapping table
S616. Send IPv6 network rejoin confirmation message
S617. Record in mapping table and replace IPv6 header with ZigBee network layer header
S618. Send ZigBee network rejoin confirmation message
S619. Send ZigBee data
S620. Replace ZigBee network layer header with IPv6 header
S621. Send IPv6 data
S622. Replace IPv6 header with ZigBee network layer header
S623. Send ZigBee data

Fig.6

# INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2013/001840

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L29/06
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | REEN-CHENG WANG ET AL: "Internetworking Between ZigBee/802.15.4 and IPv6/802.3 Network", IEEE, vol. 8021543, 1 August 2007 (2007-08-01), XP55088015, | 1-9,12 |
| A | the whole document | 10,11,13 |
| | --- | |
| A | US 2012/099579 A1 (KIM YEON-SOO [KR] ET AL) 26 April 2012 (2012-04-26) the whole document | 1-13 |
| | --- | |

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 13 December 2013 | 20/12/2013 |

| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040,<br>Fax: (+31-70) 340-3016 | Tyszka, Krzysztof |

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2013/001840

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| US 2012099579 A1 | 26-04-2012 | KR 20110003209 A | 11-01-2011 |
| | | US 2012099579 A1 | 26-04-2012 |
| | | WO 2011002177 A2 | 06-01-2011 |