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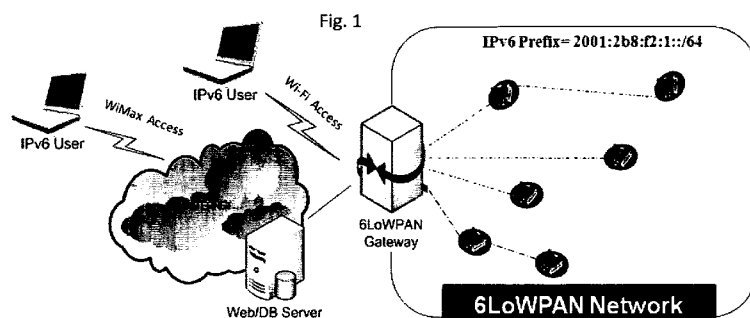
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(54) Title: METHOD OF COMMUNICATING SIGNALS IN 6LOWPAN NETWORK TO IPV6 NETWORK



(57) **Abstract:** A service module of a gateway for communicating 6LoWPAN network to IPv6 network is described. The module describes a network join packet to establish initial connection between 6LoWPAN network and IPv6 network. Predetermined IPv6 prefix is added to EUI-64 address to generate a mapping table of IPv6 prefix to EUI-64 address. The gateway supports pull-based and push-based communication system. In pull-based communication system, an IPv6 client request data from a particular node. The node replies the request with sensor data to IPv6 client. Push-based communication is used when 6LoWPAN nodes proactively sends data to a dedicated IPv6 remote station.

**METHOD OF COMMUNICATING SIGNALS IN 6LOWPAN NETWORK TO IPV6
NETWORK**

5 The present invention relates generally to enterprise gateway of network communications, more particularly to a gateway for 6LoWPAN and IPv6 network.

BACKGROUND OF THE INVENTION

10 6LoWPAN is an acronym of IPv6 over Low power Wireless Personal Area Networks and specified in IEEE 802.15.4 standard. An enterprise gateway for 6LoWPAN usually consists of an interface module which consist of media access technology for 6LoWPAN network, a back-end module which consists of multiple media access technologies connecting to the IP network, and a service module, also known as gateway controller, which bridges the network module and back end module. The
15 service module plays a role for enabling interconnectivity between 6LoWPAN network and IP network.

However, there are several unresolved issues for connecting 6LoWPAN network to external IP network. There is no detail architecture that connects 6LoWPAN network
20 with external IP network. There is no architecture to support both 6LoWPAN packet and IPv6 packet at the same time. Current 6LoWPAN uses general routing table mechanism to route the packet to external IP network. This mechanism introduces routing complexity such as complex routing protocols, higher processing usage and higher latency.

25 US patent application 2009/0073983 describes a gateway for IPv6 packet transmission in a wireless LAN system. The gateway takes over the TCP/IP protocol stack from a legacy 6LoWPAN node for providing a gateway for IPv6 packet transmission in a wireless LAN system. A virtual interface is generated for allocating
30 IPv6 addresses to the 6LoWPAN nodes by adding a predetermined IPv6 address prefix to addresses of the 6LoWPAN nodes set in the service request messages.

US patent application 2009/0146833 provides a coordinator, gateway, and transmission method for applying IPv6 in a wireless sensor network. Dual addressing
35 of a link local address using short address and a global unicast address is provided to support data communication with an external network.

Till now there is no decision module to select the best interface for heterogeneous network. It is an object of the invention to provide a decision module to forward relevant packets to heterogeneous networks including 6LoWPAN network.

5

SUMMARY OF THE INVENTION

The present invention proposes a solution which comprises a service module integrated in an enterprise gateway which consists of a set of component for packet handling so that it can ensure connectivity between 6LoWPAN gateway and IP
10 network. The service module consists of a component which has the ability to select the best interface to route the packets. The selection of interface is based on dynamic priority based routing. This mechanism gives different priority for different interfaces to route the packet to backhaul based on current condition of the links.

15 The module includes a capability of handling IPv6 traffic from multiple different access technologies, and differentiating between incoming 6LoWPAN request and normal IPv6 packet. It also includes the capability of handling traffic originating from 6LoWPAN network towards various enterprise IP subnets. Hence, it allows nodes in 6LoWPAN network to communicate natively with any other IP devices in the
20 enterprise network regardless of media interface.

The packet handling component has the ability to listen, analyze and handle traffic from 6LoWPAN network. The packet handling component also handles IPv6 traffic from multiple different media links. Hence, 6LoWPAN packet can be translated into
25 IPv6 packet format or vice versa.

This architecture can be used for pull-based communication system or push-based communication system. In pull-based communication system, when IPv6 client requests sensor data from a particular 6LoWPAN node, the node reactively replies
30 the request with sensor data to IPv6 client. In push-based communication system, the 6LoWPAN nodes proactively initiate communication by sending sensor data to IPv6 remote station.

BRIEF DESCRIPTION OF THE DRAWINGS

35

The invention will now be described in greater detail, by way of an example, with reference to the accompanying drawings, in which:

Fig. 1 shows an overview of 6LoWPAN gateway connecting 6LoWPAN network with IPv6 network;

5 Fig. 2 shows a diagram of 6LoWPAN gateway dual stack protocol;

Fig. 3 shows a diagram of general enterprise gateway architecture;

Fig. 4 shows a diagram of 6LoWPAN gateway architecture;

10

Fig. 5 shows a diagram of IPv6 address assignment to 6LoWPAN nodes;

Fig. 6 shows examples of sensor node mapping table;

15 Fig. 7 shows a diagram of IPv6 packet transformation;

Fig. 8 shows a flow chart of packet transformation from external network to 6LoWPAN network;

20 Fig. 9 shows a flow chart of packet transformation from 6LoWPAN network to sensor node;

Fig. 10 shows a diagram of pull-based communication system; and

25 Fig. 11 shows a diagram of push-based communication system.

DETAILED DESCRIPTION OF THE DRAWINGS

30 It is desirable to connect 6LoWPAN network with other IP networks in order to maximize utilization of information and resources. This integration allows access across 6LoWPAN and IP networks.

35 As shown in Fig. 1, a typical architecture of 6LoWPAN comprises IPv6 user, 6LoWPAN gateway and 6LoWPAN wireless sensor nodes. The gateway, placed in an interconnection, resides between external IP network and 6LoWPAN network. The gateway plays an important role for providing IP connectivity to 6LoWPAN nodes.

The gateway has two main roles. Firstly, it provides a sink node for a particular 6LoWPAN network. Secondly, it simultaneously provides gateway nodes for both 6LoWPAN network and IPv6 network. The gateway enables the forwarding of sensor data between 6LoWPAN and external IPv6 network. For this reason, two protocol stacks, as shown in Fig. 2, should be present in 6LoWPAN gateway.

To provide access to 6LoWPAN network, the 6LoWPAN gateway is integrated with enterprise gateway which provides multiple access links for IP network. Ethernet, WiFi and WiMAX are some of the technologies that can be integrated with 6LoWPAN to achieve a ubiquitous wireless sensor network. The enterprise gateway for 6LoWPAN must have dual stack representing multiple PHY/MAC, eg. Ethernet, WiFi and WiMAX, for connecting external IP network and PHY/MAC of 6LoWPAN 802.15.4 standard.

Based on the above dual stack protocol, the enterprise gateway for 6LoWPAN is designed to have three modules, as shown in Fig. 3. The PHY/MAC for multiple interfaces that connects to external IP network is defined in back-end module. 6LoWPAN PHY and MAC layer are defined in 6LoWPAN module. All services that might be implemented on top of adaptation layer which includes network layer, transport layer and application layer resides in service module of the architecture.

The 6LoWPAN module consists of IEEE 802.15.4 compliance hardware which includes 6LoWPAN stack. The module is responsible for handling connectivity to 6LoWPAN network using IEEE 802.15.4 standard.

The back end module defines the Physical and MAC layer of any interface that might provide connectivity to external IP network. This module offers functionalities required to ensure connectivity to external IP network. Some of the interfaces are LAN, WiFi, Ethernet and WiMAX.

The service module handles both 6LoWPAN and IPv6 packet. The services inside this module can be implemented on adaptation layer, network layer, transport layer or application layer. The invention is mainly about the service module, which will now be described.

As shown in Fig. 4, the architecture and relationship among the gateway modules is further expanded. A node discovery component is used as a service that discovers a list of node as well as telling nodes in 6LoWPAN network about their gateway. The node discovery can be active or passive. For active discovery, the gateway will periodically broadcast gateway advertisement packet from 6LoWPAN module to 6LoWPAN network. The nodes will provide advertisement response packet to this advertisement. Using this option, the gateway can retrieve any existing sensor node available within 6LoWPAN network. Moreover, the nodes will also know their gateway to IP network. The cycle of advertisement and advertisement response packet is defined as a network joining process where the nodes join in the network by sending advertisement respond packet to the gateway. In addition advertisement response packet can also be used to translate all sensor nodes of 6LoWPAN address to IPv6 address and store them into a mapping table. Thus, the mapping table for address translation purposes will be generated through network joining process.

The translation is performed after receiving advertisement respond packet by adding predetermined 64-bit IPv6 prefix to MAC address of sensor node. So, the gateway manages the pseudo IPv6 address of the sensor node. Therefore, the gateway can ignore the process of sending out prefix advertisement to 6LoWPAN network. The IEEE defined 64-bit extended unique identifier (EUI-64) of a 6LoWPAN device can be used as interface identifier of IPv6 address while predefined IPv6 prefix is used as network identifier. Moreover, EUI-64 address is globally unique so that the mapping of address is unique. Fig. 5 shows the address translation described. Examples of IPv6 address and EUI-64 address is shown in Fig. 6.

A periodical data logger is used during the logging process of sensor data in a remote station or database server. The process involves receiving sensor data from sensor nodes and updating the database with this data periodically, such as 1 hour. Unlike the mapping table which is generated automatically through node discovery process, a predefined remote station is defined manually on the gateway to manage IPv6 address of a dedicated remote station. This process can be used to update the database server.

An IPv6 router advertisement component is used to advertise IPv6 prefix into a private network so that any terminal within the private network can have connectivity with 6LoWPAN network.

Once an IPv6 user sends a request to a sensor node in 6LoWPAN network, the IPv6 packet handler which has a packet analyzer capability will handle the IPv6 packet received by any network interface in back-end module. The analyzer verifies the header of the packet if it is addressed to 6LoWPAN network. One IPv6 packet can be recognized to be routed into 6LoWPAN network by comparing the prefix of destination address for predefined prefix of 6LoWPAN network. An example of sensor's IPv6 prefix as assigned by the gateway is 2001:2B8:F2:1:/64, as shown in Fig. 1.

If the packet is addressed to 6LoWPAN network, it will map the IPv6 address into 6LoWPAN address by using mapping table. The packet is transformed into 6LoWPAN through packet transformation process, so that it can be understood by nodes in 6LoWPAN network. After these processes the packet handler through packet forwarder component will relay the packet to Personal Area Network (PAN) Coordinator at 6LoWPAN modules which will later be forwarded to 6LoWPAN network.

Packet transformation is performed, as shown in Fig. 7, by taking payload of the packet and combine with necessary packet headers which are either IPv6 header or 6LoWPAN header. 6LoWPAN packet coming to 6LoWPAN module will be passed to packet handler through packet analyzer. The packet analyzer is actually a decision module which identify network join packet, response to IPv6 packet or periodical packet which push data into dedicated IPv6 remote station. After identifying the packet, translation of 6LoWPAN packet to IPv6 packet is performed. After this process, the packet handler will decide to forward the packet to one of network interface at back-end module. If the prefix of IPv6 destination address of packet is similar to the prefix configured in router advertisement, the packet will be forwarded to LAN/WLAN interface-1 eg. WiFi, otherwise it will be forwarded to internet backhaul connection. Interface-2 is a priority connection to internet backhaul, if interface-2 is inactive, interface-3 eg. WiMAX will be used to forward the packet to internet.

Fig. 8 shows a flow chart explaining the process when packets from external IPv6 network arrive at gateway requesting sensor data from 6LoWPAN node. The packet is analyzed if it is IPv6 packet. If it is IPv6 packet, then it is analyzed if it is addressed to 6LoWPAN network. The packet is discarded if it is not IPv6 packet or addressed to 6LoWPAN network. Next, the mapping table is checked if destination

address exists in the table. The packet is discarded if there is no match. If a match exists, the destination IPv6 address is mapped to EUI-64 address. Then, the IPv6 requestor address is kept. The header of IPv6 packet is next changed to 6LoWPAN packet. Finally, the packet is ready to be forwarded to 6LoWPAN network.

5

Fig. 9 shows another flow chart detailing the process when a packet from 6LoWPAN node is received by gateway. The packet arrives at 6LoWPAN module which is compatible with IEEE 802.15.4 interface. Next, the 6LoWPAN packet is analyzed if it is a network join packet, said network join packet having EUI-64 address of node. If it is a network join packet, predetermined IPv6 prefix is added to EUI-64 address of the node. Then, a mapping table of IPv6 prefix to EUI-64 address of node is generated for address translation. The data is updated in IPv6-EUI mapping table.

If the 6LoWPAN packet is not a network join packet, the packet is analyzed if it is a response packet to a requestor. If it is a response packet from requestor, the IPv6 requestor address is obtained and set as destination address. A matching IPv6 address of EUI-64 source address is retrieved from mapping table. The header is then changed from 6LoWPAN packet to IPv6 packet.

If the 6LoWPAN packet is not a response packet to requestor, the packet is verified if it is a periodical packet sending data to remote station. If it is a periodical packet, the predefined remote station's IPv6 address is obtained from the gateway and set as destination address. Similar as previous header change, the header is changed from 6LoWPAN packet to IPv6 packet. The packet is discarded if it is not a periodical packet to the remote station.

The changed IPv6 packet is forwarded to external IP network. The packet is analyzed if it is addressed to WLAN or WiFi network. The packet is forwarded to WLAN or WiFi network if it matches. Next, the packet is analyzed to select the best interface to route the packet to backhaul based on priority based mechanism. The best is selected among interface 1 of WiMAX, interface 2 of Ethernet or interface 3 of WiFi.

The gateway supports pull-based and push-based communication system. Pull-based communication is used in a scenario when IPv6 client request sensor data from a particular 6LoWPAN node. The node reactively replies the request with

sensor data to IPv6 client. Push-based communication is used when 6LoWPAN nodes proactively sends data to a dedicated IPv6 remote station.

Fig. 10 shows a pull-based communication system which shows the process of IPv6 user A, residing in IPv6 network, communicating with node B located at 6LoWPAN network through gateway G, the 6LoWPAN coordinator.

The network join process is an initiation step to form a 6LoWPAN network. Gateway performs node discovery through gateway advertisement packet GW_ADV. This process lets node B to join the 6LoWPAN network by responding with advertisement response packet ADV_RESPONSE. The advertisement packet is translated by adding predetermined IPv6 prefix to EUI-64 address of node and stored in a mapping table.

After the network join process is complete, IPv6 user can directly access or request data from 6LoWPAN nodes through gateway. IPv6 user A sends a request in IPv6 packet to node B through gateway G. The IP address is a pseudo IPv6 address of node B ($IP_B = \text{IPv6 prefix} + \text{EUI-64}$). When gateway G receives the packet, it then translates IPv6 destination address IP_B to EUI_B which is 64-bit length. The gateway transforms IPv6 packet into 6LoWPAN packet and forward the packet to node B. The extended address for both source ($SRC = EUI_G$) and destination address ($DST = EUI_B$) is also communicated. After retrieving sensor data, node B ($SRC = EUI_B$) will send sensor data to gateway EUI address EUI_G ($DST = EUI_G$). At gateway, EUI_B will be translated into IP_B before transforming the packet into IPv6 packet and send the sensor data out to IPv6 user A.

The push-based communication system is shown in Fig. 11. The communication is initiated by Node B through gateway G to user A of a remote station using IPv6 network. Sensor nodes need to send periodical data to remote station. In this case, the gateway must be manually predefined with dedicated remote station IPv6 address.

Similar as pull-based communication system, push-based communication has the same network join process. After a 6LoWPAN network is established, sensor node B generates and sends periodical data to gateway G. After analyzing the packet header, the gateway should know that it is periodical packet that must be forwarded to a dedicated remote station. Since the gateway is already predefined with IPv6 address of remote station, the process is then followed by replacing 6LoWPAN

header with IPv6 header which transforms the 6LoWPAN packet into IPv6 packet. The IPv6 packet is then relayed to remote station. This operation is used when database server needs to be updated periodically.

- 5 Accordingly, the invention disclosed a service module for a gateway. Initial connection is established by network join method described. Approaches were described for IPv6 network to retrieve data from 6LoWPAN network. The communication systems, comprises a 6LoWPAN network at a first site, a gateway using methods described; and an IPv6 network at a third site. Signals at the first site
10 are connected to the second site and signals at the second site are connected to the third site.

- It is the combination of the above features and its technical advantages give rise to the uniqueness of such invention. Although the descriptions above contain much specificity, these should not be construed as limiting the scope of the embodiment
15 but as merely providing illustrations of some of the presently preferred embodiments.

CLAIMS

1. A method of communicating signals in 6LoWPAN network to IPv6 network, comprising:
 - 5 providing network join packet in 6LoWPAN packet, said network join packet having EUI-64 address of node;
adding predetermined IPv6 prefix to EUI-64 address of node;
generating a mapping table of IPv6 prefix to EUI-64 address of node for address translation;
 - 10 providing a 6LoWPAN packet from 6LoWPAN node;
retrieving destination address in IPv6 address;
changing the header of 6LoWPAN packet to IPv6 packet; and
forwarding the IPv6 packet to destination address.
- 15 2. A method according to claim 1, further comprising discovering a list of 6LoWPAN node in the network.
3. A method according to claim 1, wherein network join packet is provided after broadcasting gateway advertisement packet to 6LoWPAN nodes and receiving advertisement response packet if node is available.
- 20 4. A method according to claim 1, wherein network join packet is provided by periodically broadcasting gateway advertisement packet to 6LoWPAN nodes and receiving advertisement response if node is available.
- 25 5. A method according to claim 1, further comprising:
 - providing IPv6 packet addressed to 6LoWPAN network, having destination address that match with EUI-64 address of mapping table;
 - mapping destination IPv6 address to matching EUI-64 address;
 - 30 keeping IPv6 requestor address;
 - changing the header of IPv6 packet to 6LoWPAN packet;
 - forwarding the packet to 6LoWPAN network.
6. A method according to claim 5, further comprising:
 - 35 providing a response packet in 6LoWPAN packet;
 - getting IPv6 requestor address and setting it as destination address; and

retrieving matching IPv6 address of EUI-64 address source from mapping table.

7. A method according to claim 1, further comprising:
- 5 defining remote station access to receive 6LoWPAN packet;
 providing periodical packet sending data in 6LoWPAN packet to remote station; and
 providing predefined remote station IPv6 address as destination address in periodical packet.
- 10
8. A method according to claim 1, further comprising forwarding the packet to wireless LAN network if it is addressed to the network.
9. A method according to claim 1, further comprising forwarding the packet to
- 15 Ethernet network.
10. A method according to claim 1, further comprising forwarding the packet to WiMAX network.
- 20 11. A communication systems, comprising:
 a 6LoWPAN network at a first site;
 a gateway using methods as claimed in any of the preceding claim at a second site; and
 an IPv6 network at a third site;
- 25 signals at the first site being connected to the second site and signals at the second site being connected to the third site.

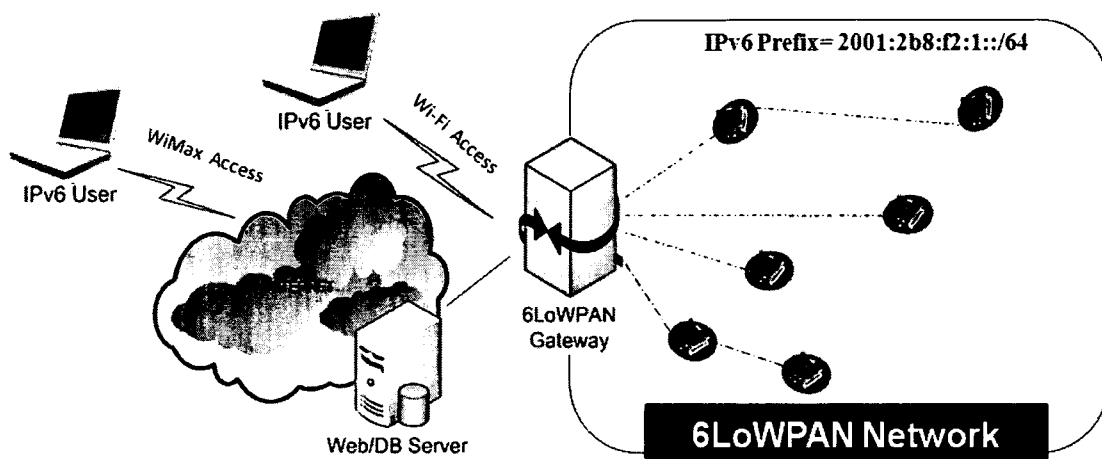


Fig. 1

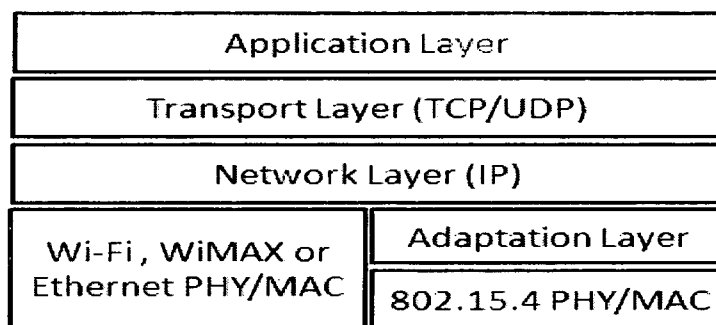


Fig. 2

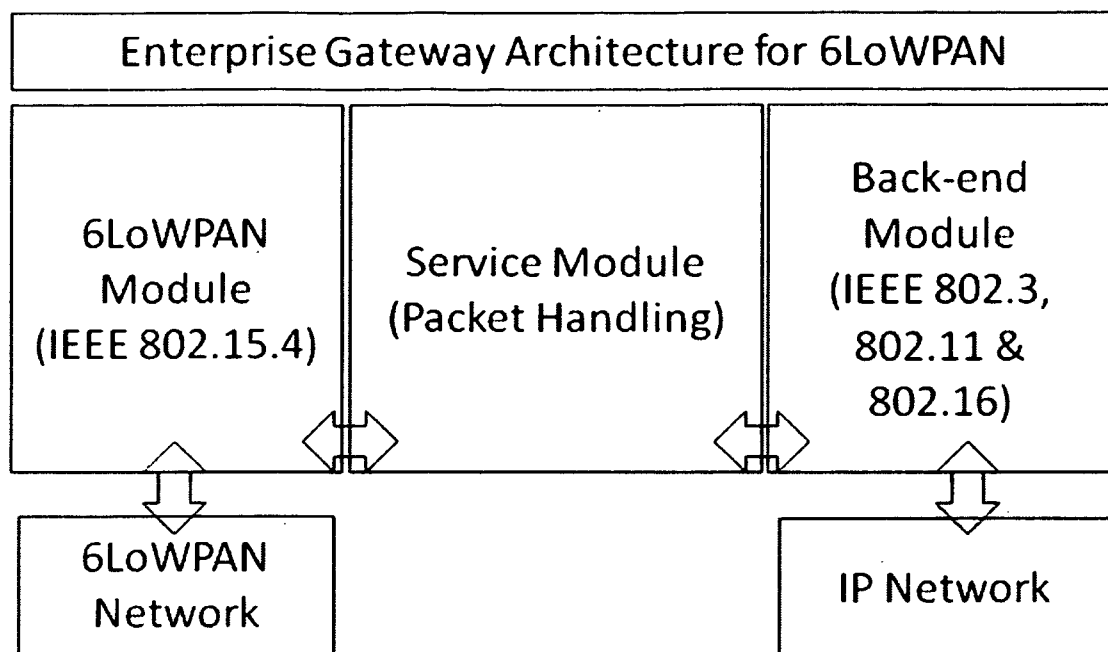


Fig. 3

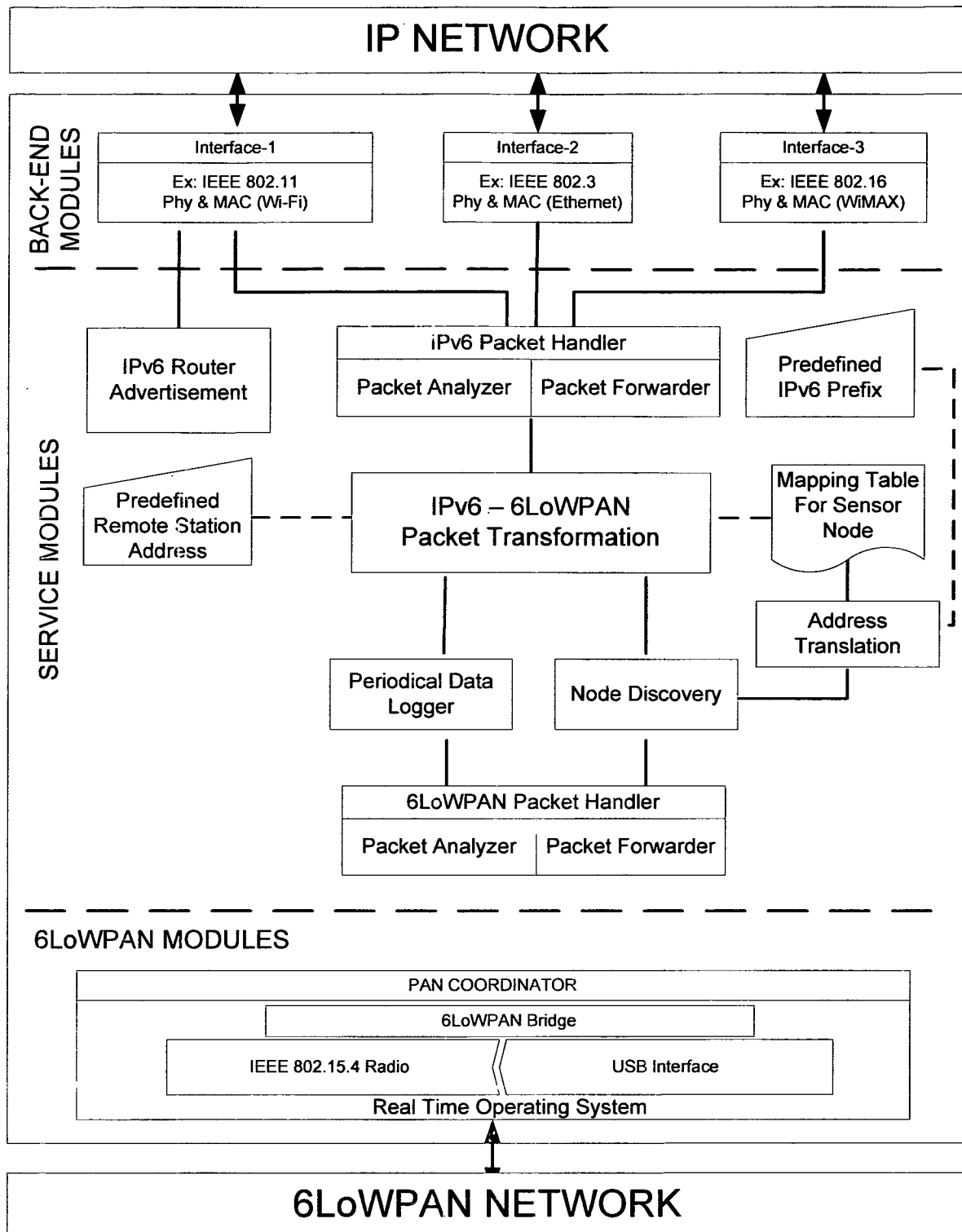


Fig. 4

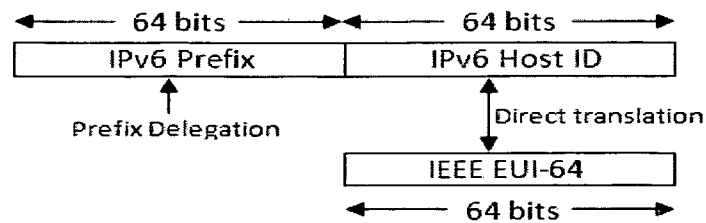


Fig. 5

IPv6 ADDRESS	EUI-64 MAC ADDRESS
2001:2B8:F2:1:6D10:200:20:1500	6D:10:02:00:20:15:00
2001:2B8:F2:1:5E10:200:20:1500	5E:10:02:00:20:15:00

Fig. 6

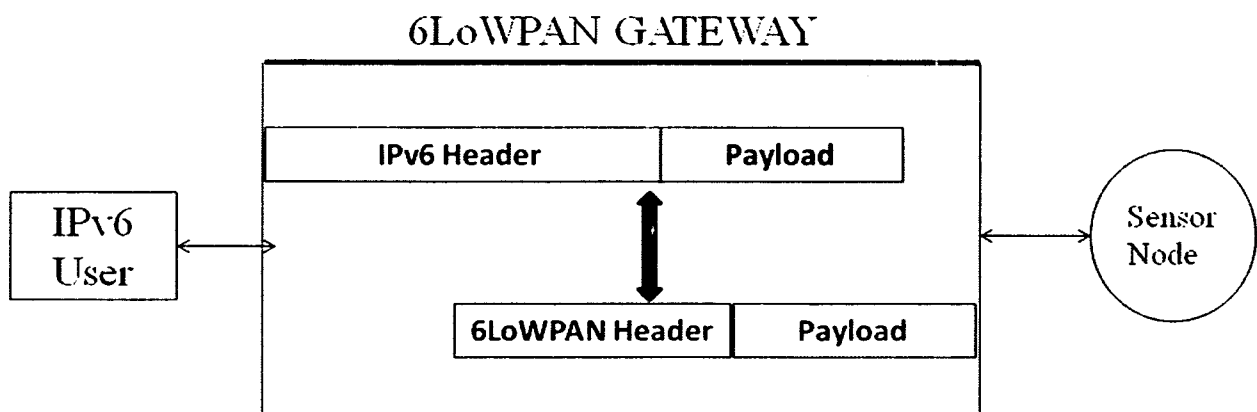


Fig. 7

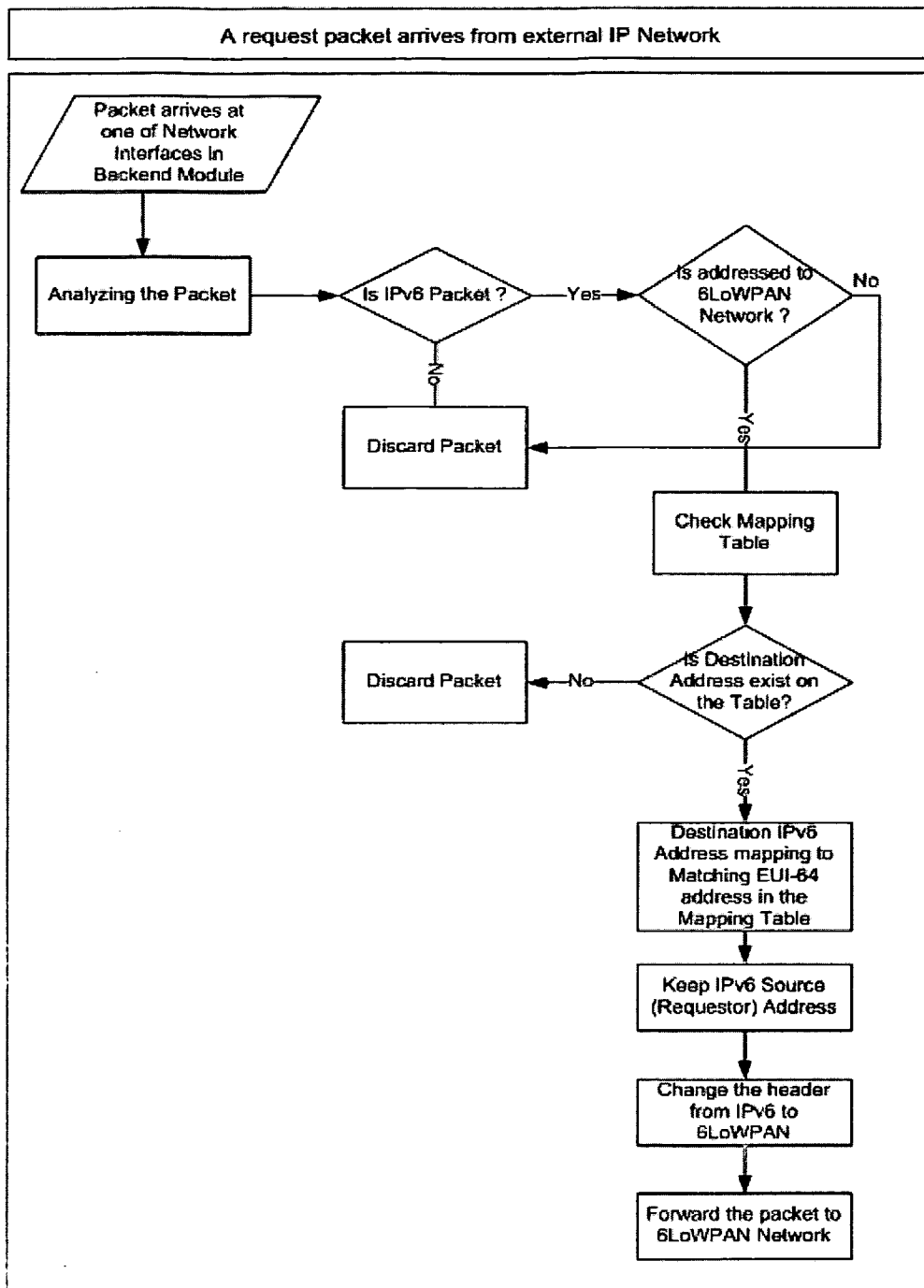


Fig. 8

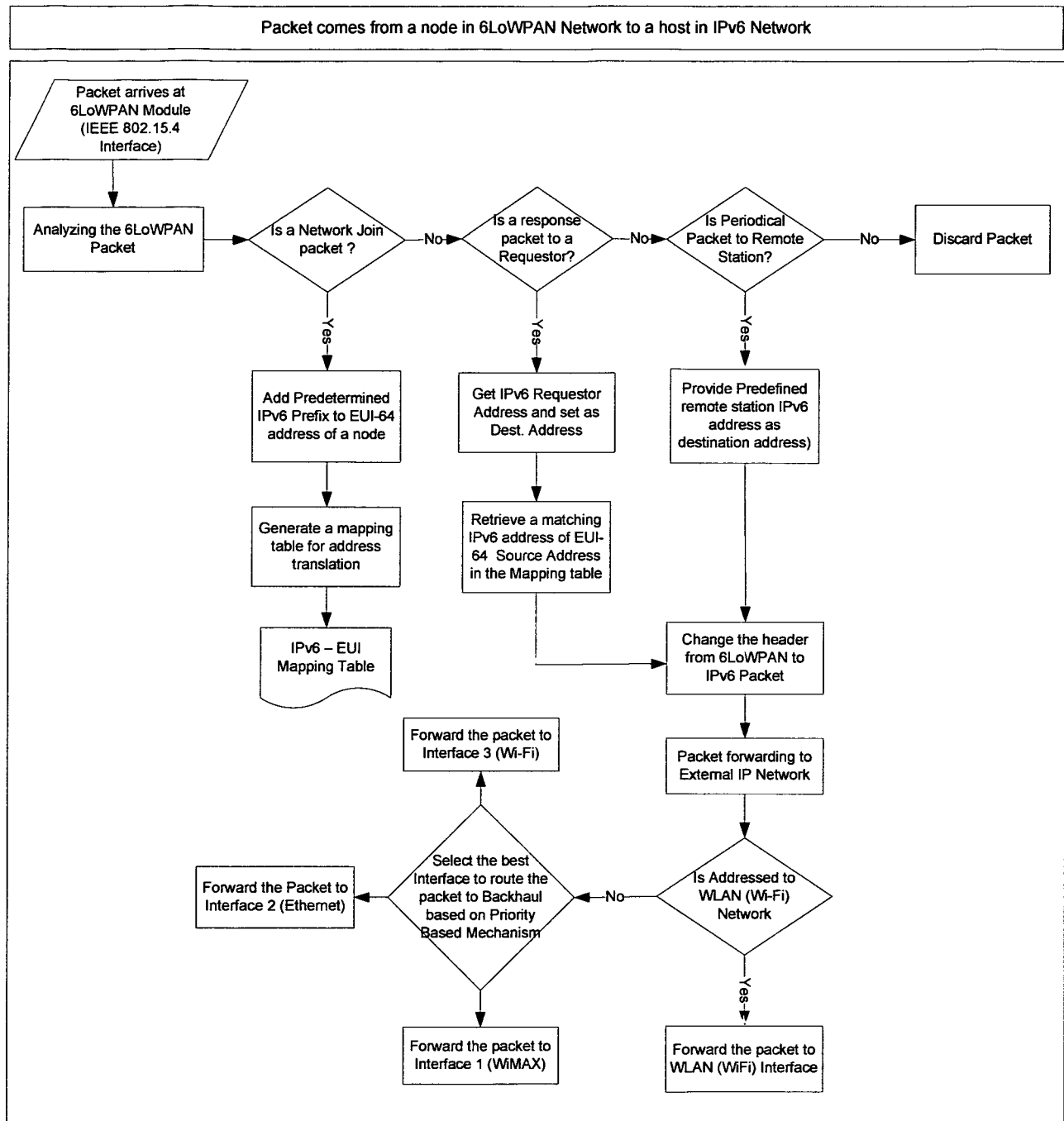


Fig. 9

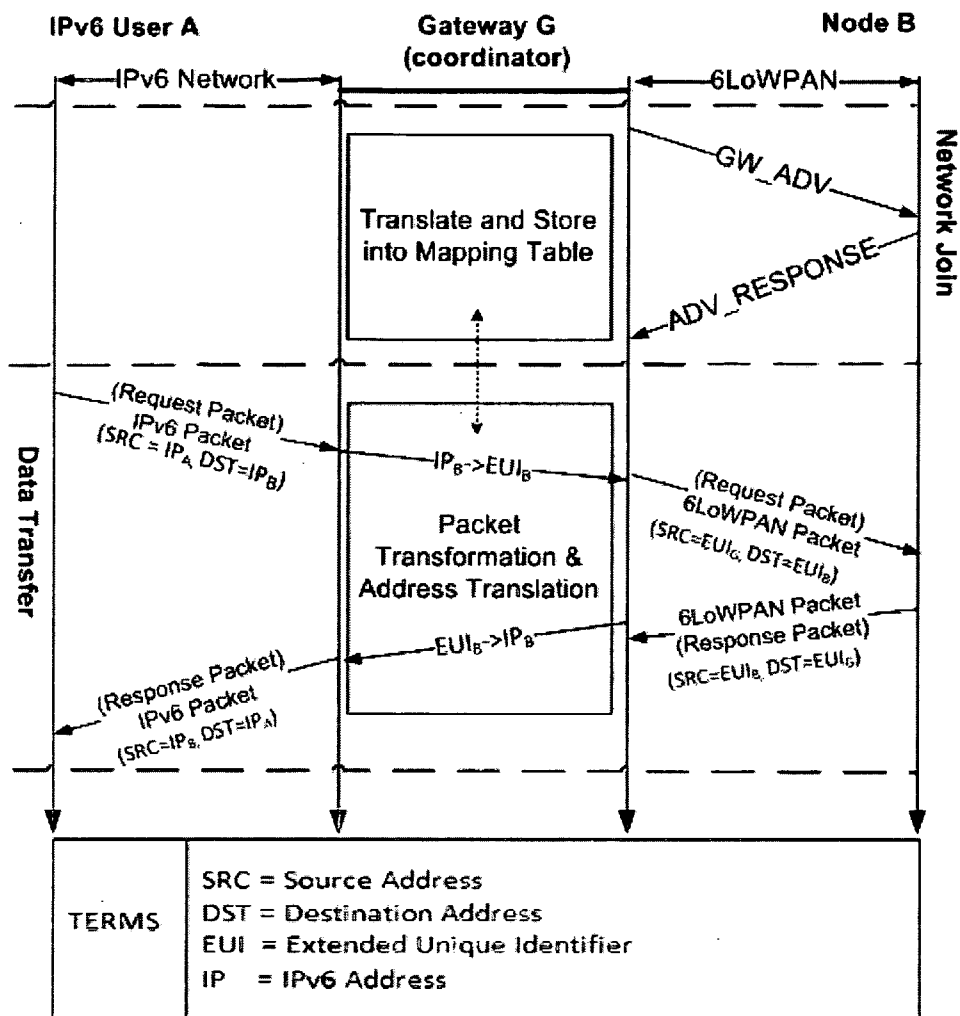


Fig. 10

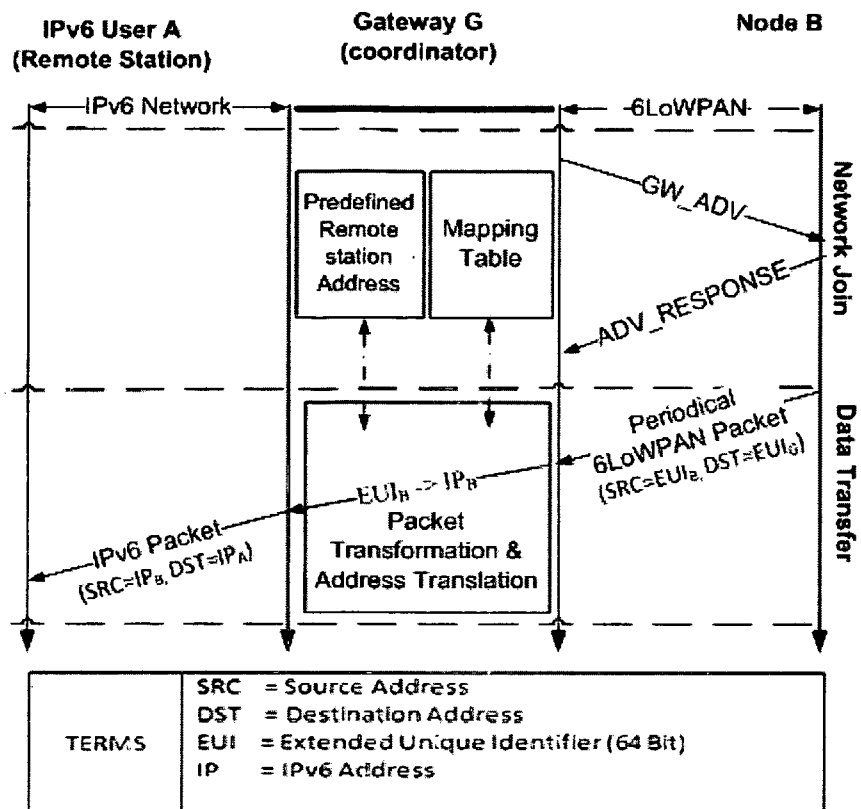


Fig. 11

INTERNATIONAL SEARCH REPORT

International application No.

PCT/MY2011/000031

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

H04W 8/06 (2009.01)**H04L 29/06** (2006.01)**H04L 29/12** (2006.01)

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)

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)

TXTE and GOOGLE SCHOLAR INTERNET SEARCH: 6LoWPAN, zigbee, IPv6, 802.15.4, 802.3, network, internetworking, mapping table, EUI and other terms and phrases.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Wang, R-C et al.; "Internetworking between Zigbee/802.15.4 and IPv6/802.3 Network"; SIGCOMM Workshop, Kyoto, Japan; 31 August 2007. Figures 3-6; Section 3.1, 4.1 & 4.3	1-11
A	US 2009 / 0161581 A1 (KIM) 25 June 2009 Abstract	
A	US 2009 / 0185549 A1 (SHON et al.) 23 July 2009 Abstract	



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02 September 2011Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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PCT/MY2011/000031

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