IPV6 Address Configuration Method in 6LoWPAN Oriented to the Internet of Power Things

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Abstract. Taking the location information as the focus, we analyze the accurate algorithm of the location-based 6LoWPAN network to automatically configure the address, and conducts a feasibility study. The main content includes the establishment of a LINA network architecture based on location information. Based on the location information of the node, the router at the edge is used as the center, and the plane projected on the 6LoWPAN network is used as the medium to form many grids and achieve the goal of rapid clustering; each grid is independent of each other and can configure the address effectively at the same time, so that the delay of the network can be greatly reduced; the feasibility of the address configuration scheme is verified by comparing the overhead of the traditional address configuration scheme .

Keyword: Power Internet of Things · 6LoWPAN · IPV6 · Address configuration

1 Introduction

The power Internet of Things has developed rapidly, and the current IPv4 protocol cannot satisfy the increasingly diversified needs; therefore, the new IPv6 protocol came into being. It has a 128-bit address and rich resources. It can basically satisfy the requirements of uniform addressing of nodes for the power Internet of Things on a theoretical level [1]. However, the current Internet of Things has the characteristics of low broadband and power consumption, which hinders the effective use of the IPv6 protocol. IETF proposed the 6LoWPAN protocol in response to the above situation, which means that devices with low-level power consumption provide strong support for the realized IP functions, that is, the low-power network of the power Internet of Things and the Internet based on IPv6 are seamlessly connected, and unified Addressing function. 6LoWPAN has become a crucial key technology in the development of the field of power Internet of Things, making the power Internet of Things more widely used [2].

In recent years, the main content of the industry research is the 6LoWPAN low-power configuration solution for the underlying network address. According to the need for

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DAD conflict detection, it is divided into the following types (1) Conflicting configuration address protocol. It repeats detection for the generated address and makes its unique attributes verified; (2) Configure the address protocol without conflict. It uses neighbor proxy methods to assign and decentralize address tasks to network nodes.

Based on the allocation of IP addresses to nodes, the low-power bottom nodes in the 6LoWPAN network and the corresponding devices in the IP network can communicate with each other [3]. Based on a conventional wired network, the address is effectively configured through IPv4 and IPv6 protocols; the configuration method covers the following types [4]: (1) Automatic configuration, whether there is a central server or not, it can be divided into the two types of stateful and stateless; (2) Manual configuration. Both IPv4 and IPv6 support it. When the number of network nodes is relatively small, the address is manually configured to each node. If the number of nodes is large and the IPv6 address has extremely long, manual configuration mode is not suitable, so it will be a crucial link to automatically obtain IP when loading nodes in the network. In the past, when the IP network realized the automatic configuration address function, IPv4 provided a protocol for stateful automatic configuration address, which was realized by the DHCP server. After further improvement and improvement, IPv6 as a new IP protocol that [5] it provides support for stateless addresses while making the configuration extremely flexible and convenient. The automation of stateful address configuration is usually based on the DHCP or DHCPv6 server to configure the IP address of the terminal device to the Internet, which means that the server/client mode of operation is adopted [6]. The server is the center to store the status information of each node and the corresponding addresses that have been allocated to it, and the allocation table is constantly updated and improved. If a new node is added to the network, a request for address application will be made to the central server. After receiving the corresponding request, the server will assign the address to the corresponding node [7]. After obtaining the address from the server, the node returns to the server and clarifies the information. After the server receives the corresponding information, it records the corresponding information of the assigned node in the address allocation table [8].In smart grids, an energy metering system is a subset of smart energy, which is used to solve energy metering and metering data management functions in smart energy [9].

2 Introduction of 6LoWPAN

2.1 IPv6 Addressing of 6LoWPAN Network

The Internet of Power Things has developed rapidly, and the currently adopted IPv4 protocol cannot satisfy the increasingly diversified needs; therefore, the new IPv6 protocol came into being, with a 128-bit address and abundant resources, which can basically provide every drop of water a unique identifier based on the theory [5]. It is in line with the requirement that IoT nodes can be addressed uniformly. However, the current embedded network has the characteristics of low broadband and power consumption, which hinders the effective use of the IPv6 protocol. The IETF proposed the 6LoWPAN protocol in response to the above situation, which means that devices with low-level power consumption provide strong support for the realized IP functions, that is, the low-power network of the Internet of Things and the Internet based on IPv6 are seamlessly connected, and unified search is realized. The function of 6LoWPAN has become a crucial key technology in the development of the Internet of Things and makes the Internet of Things more widely used [7]. For the IP-based Internet, in order to communicate with each other normally and smoothly, the legality of IP addresses needs to be unique [8]. As a new model for constructing networks, 6LoWPAN needs to effectively solve the problem of configuring IP addresses, so that it can be used freely and connected with other networks. Based on the existing IP network, nodes generally obtain corresponding addresses through existing state or stateless configuration addresses. If the solution of stateful address configuration is adopted, it refers to the effective configuration and management of corresponding addresses for network terminals via the mode of DHCPv6 and Internet broadcasting. IPv6 address covers the link between prefix and interface identification. The length of the address is 128 bits, and each segment is 16 bits. Each segment can be turned into hexadecimal numbers and separated; IPv6 addresses can be divided into the following types: first, unicast. The destination address is effectively specified for a host or router, that is, the identifier corresponds to a single interface; second, anycast. The destination station shares a set of nodes in a certain address, selects the shortest path through datagrams, and then delivers to the group members; third, multicast. The destination station is a group of addresses, and the datagram is delivered to the group members in the form of multicast or broadcast. In smart grids, an energy metering system is a subset of smart energy, which is used to solve energy metering and metering data management functions in smart energy [9].

IP addressing combines the prefix of the underlying wireless personal area network with the link layer address of the interface to generate an IPv6 address. The length of the address is 128 bits, which are the routing prefix and the interface identifier. The nodes of the same 6LoWPAN network share the prefix of the route, which can be obtained by the broadcast message of the link; the 16-bit short address is generated according to the 64-bit interface identifier. The following figure describes the IPv6 structure diagram (Fig. 1).

Global routing prefix	0000	00FFFE00	16-bit short address
64bit	16bit	32bit	16bit

Fig. 1. IPv6 structure diagram

3 Location-Based Information Network Architecture

In the power Internet of Things, the location information between nodes can express the distance and directionality of nodes in the physical space, and the nodes themselves have natural similarities and differences. Through in-depth analysis of the location information, some common problems can be solved more effectively. For example, through the similarities and differences of the location information, the corresponding address identification can be formed through the information, and the task of stateless automatic address configuration can be conveniently completed. In addition, through the distance and directionality of the location information in the node address information, the route can be easily determined, so that the overhead of routing addressing is greatly reduced. Therefore, in the process of 6LoWPAN network application, the design idea of addressing through location information has remarkably huge promotion and application prospects and needs further development.

This article applies the distance, direction and similarities and differences of node location information, and on the basis of 6LoWPAN network characteristics and technical research, we analyze the address configuration scheme based on location information. Figure 2 is a network topology diagram based on location information:

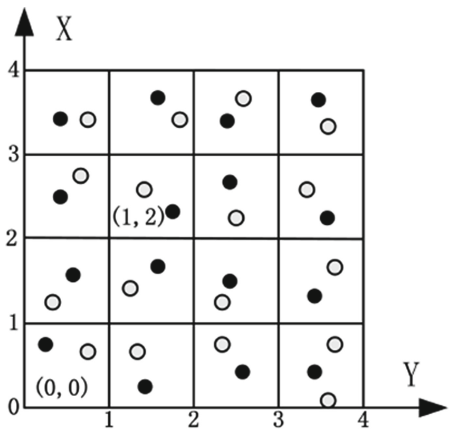

Fig. 2. 6LoWPAN network topology diagram based on network grid

When constructing the relevant network framework for location information, the 6LoWPAN network must first be divided into a number of virtual network two-dimensional grids according to the number of nodes and network coverage [37]. The area of one grid is represented by S, following with the formula $S = (mr)^2$. r always represents the wireless transmission radius of the node, and m is customized according to the number of nodes in the grid (it is a positive integer). We set the coordinates of the edge router (0, 0) and each grid is identified by the coordinates (X, Y). The node is connected to the network. A specific positioning method is firstly used to obtain its own positioning coordinates (Lx, Ly), and the following formula is performed to calculate the corresponding deleted grid coordinates. See the following formula for details:

$$X = \left[\frac{L_X}{\sqrt{S}} \right] \tag{1}$$

$$Y = \left[\frac{L_Y}{\sqrt{S}} \right] \tag{2}$$

The solution in this paper divides the short address (16 bits) of the 6LoWPAN network, that is, the node ID into three parts: internal ID, ordinate, and abscissa. The address length of the abscissa is i bit, and the address length of the ordinate is j bit.

We assume i and j are positive integers, and their values depend on the density and number of nodes distributed in the network. Figure 3 shows the IPv6 address structure is designed by the above network architecture. It is a network architecture based on location information. Its purpose is to complete the function of converting location information to address space, so that the location information of the node is included in the node's corresponding IPv6 address, which provides great convenience for the specific application of the 6LoWPAN network based on location information. In addition, according to the natural similarities and differences of node location information, the network achieves the function of rapid clustering without other address configuration and complicated clustering algorithms. Moreover, under the condition of a large-scale network and a large number of nodes, a very large network can be divided into multiple subnets, and all subnets are independent of each other, and address configuration can be completed simultaneously, which greatly reduces network delay and expenses.

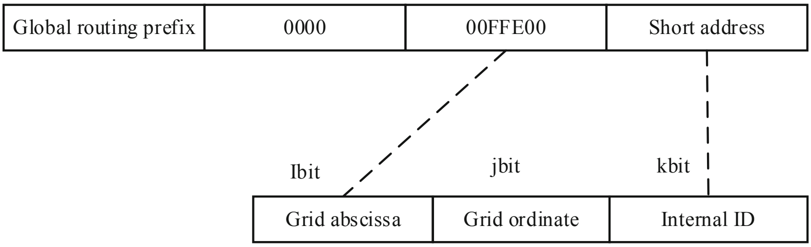

Fig. 3. IPv6 address structure based on location information address automatic configuration scheme

3.1 Node Type

In this solution, the relevant nodes in the access network specifically include three categories, and the various states of the nodes correspond to the various categories of the nodes. In the case of different states, the functions undertaken by the nodes also have certain differences. This program mainly involves the following four types of nodes:

(1) Newborn node: The node has not yet obtained a reasonable IPv6 address. It has just started to access the network, and obtain the corresponding grid ID according to its own location information, and determine the grid where it is located.
(2) Normal node: It has no redundant address, but is configured with a legal IPv6 address corresponding to it, and it cannot be configured with an IPv6 address to a new node.
(3) Proxy node: It has redundant addresses and is configured with a legal IPv6 address corresponding to it. The address space is greater than 1, and it can be configured with IPv6 addresses to new nodes.
(4) Head node: All deleted grids have 1 head node, and 1 grid is equivalent to 1 subnet. This head node is equivalent to an IPv6 router. Its function is to configure the corresponding address to the internal node of the deleted grid to communicate with each other.

When the new node approaches the network, it can obtain the corresponding grid ID. First, it will send out an address application to neighboring nodes within one hop of the surrounding area, and the proxy node will respond after receiving the request. If the neighboring nodes in the surrounding one-hop interval are all new nodes or normal nodes (that is, there is no free address), the scope will be expanded and the address application will continue. If the proxy node allocates the corresponding address to the new node with only one redundant address, then after the redundant address is allocated to the new node, the node becomes a normal node because it no longer has a spare address. The proxy node itself has redundant addresses. After configuring all the redundant addresses in the process of configuring other addresses, it will become a normal node. In the same way, when a normal node obtains other spare addresses in the network, it can also become a proxy node. If normal nodes and proxy nodes are separated from the network for various reasons, they become invalid nodes. The schematic diagram of node status changes is shown in Fig. 4.

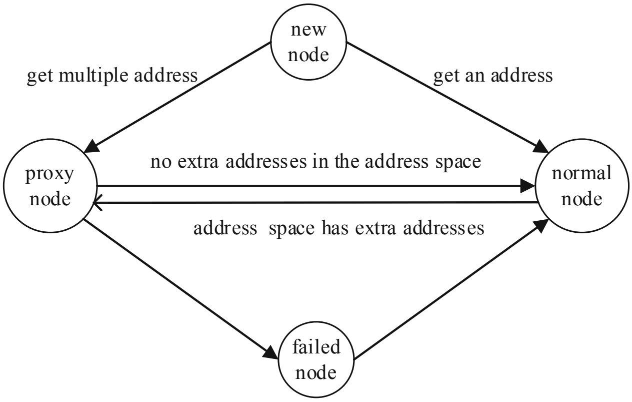

Fig. 4. Node state transition diagram on binary tree method

This configuration address scheme divides the 6LoWPAN network into several network grids (virtual) according to the location information of the nodes, and realizes the function of rapid clustering. It is assumed that all deleted grids have their own corresponding cluster head nodes (that is head node). The network architecture is the same as shown in Fig. 3. After the head node is connected to the network, it will first obtain the location information and grid ID corresponding to itself, confirm the grid where it is located, and set the internal ID corresponding to itself to 1. It combines the two stages to form a short address (16 bits) and then configure an IPv6 address, which is the same as shown in Fig. 2.4. At this time, the network initialization is complete. The head node uses the random dichotomy to configure the nodes in the grid to internal IDs, and when setting the parameters of the random dichotomy, a certain address space is set according to the number of nodes near the node that have not been configured with IP addresses to reduce the probability of unsuccessful configuration in the range of high node density in the interval during the process of address configuration, and an effective address recovery method is also applied. The node adopts the above method to automatically obtain the

16-bit short address that is allowed to be used inside the 6LoWPAN network, and does not need to detect whether the address conflicts. In addition, all grids are independent of each other, and several grids can be configured with addresses at the same time, which reduces the overhead and the delay in the process of addresses configuration.

4 Address Allocation Method

4.1 IP Address Allocation

After a new node joins the network, it needs to extract the horizontal and vertical coordinates of the deleted grid according to its own positioning information, and set a head node in each area. We set the ID of the head node to be 1. The head node covers the entire address space. When configuring the address, the configuration should be started from the head node. In the following links, a new network node is added to obtain the internal ID process. In the early stage when it does not get a unique address, the node uses its own MAC address as a temporary address when communicating.

(1) After the new node A obtains the grid coordinates, it will send the address request addr_request control packet to the neighbor nodes within one hop range, and set the hop count R (positive integer) and the number of transmissions to 1, and configure the corresponding Offer_timewait waiting clock.
(2) After the neighbor node within one hop receives the addr_request control packet, if it is judged that the received data packet is a normal node, it will discard it; if it is judged that the received data packet is a new node, it will send the addr_reply1 data packet. If it is determined that the received data packet is a proxy node, the data packet addr_reply2 is sent.
(3) After Offer_timewait waits for the time set by the clock, the addr_reply1 and addr_reply2 data packets replies from neighbor nodes are checked by node A, and the number N of new neighbor nodes within one hop is calculated, and the replying proxy node is compared with the number of free addresses W. It sends the selc_reply data packet to the proxy node B with the largest number of free addresses. If the data packet addr_reply2 from the proxy node is not received, it is confirmed that there are no neighbor nodes within one hop. Address (6).
(4) The selc_reply data packet returned by the new node A is received by the proxy node B with the largest number of free addresses. At the same time, the value of the new number field in the packet is checked, that is, the new node N with no address configured in the range of the new node A is checked. According to the value of N and the number of free addresses W (W is a positive integer ≥ 1), node B can generate a random number M to determine the number of addresses allocated to new node A.
(5) After the addr_ack control data packet sent by the proxy node B is received by the new node A, it can obtain its own internal ID, construct the 16-bit short address together with the internal ID and the grid ID, and then calculate with the obtained corresponding IPv6 address. At the same time, node A checks the number M of addresses assigned to it by proxy node B. If it is $M \geq 2$, it will mark itself as a proxy node, and if $M = 1$, it will mark itself as a normal node.

(6) When node A cannot find an available address in the neighboring node within one hop, it will send the addr_reques address to expand the range of the control packet, and also actively increase one hop, and at the same time, the number of transmissions and the number of channels R are both set to 2.
(7) After the neighbor node H receives the addr_reques packet, when it is a normal node or a new node, it will discard it without processing. When it is a proxy node, it will reply the addr_Reply2 packet to the node. It set the hop count R value in the data packet to 2, and the free address number fre-addr number field value to 0.
(8) After node A transmits the selc_reply data packet to the proxy node H that answers the fastest, it also sets the value of the new number field of the new node to 0.
(9) After receiving the selc_reply data packet, the proxy node H allocates its own W12 addresses to node A by sending the addr_ack data packet, and updates its own address space and node type. After receiving the reply, node A updates its address table while obtaining the address. If there are redundant addresses, it will mark itself as a proxy node; if there are no redundant addresses, it will mark itself as a normal node.

If node A is within the range of two hops and does not receive a reply after sending the address request within the specified time, it will continue to send the request to expand the address allocation range. As mentioned above, this is the value of the expanded hop count R. The value of R is equal to the set maximum value of hops Rmax. When configuring the IP address of the 6LoWPAN network, it can be distinguished into four different types according to the various roles played by the nodes. See Sect. 3.1 for specific definitions. At the same time, all types of nodes have their own address tables, focusing on recording their addresses and address spaces. When recording, new nodes or normal nodes only record their IP addresses, but before the new node has a unique address, its temporary address is replaced by the node's MAC address. The address table of the proxy node records its own spare address set and the number of addresses, as well as its own address. If there are consecutive addresses, it is required to synchronously record the number of consecutive addresses at the lower limit (start address) of the consecutive address set.

4.2 Address Recycling

The nodes of the 6LoWPAN network will use batteries for energy supply. Because the battery has a certain storage capacity and is affected by environmental factors such as floating wireless signals, the network nodes are often disconnected for different reasons. Therefore, before the node is disconnected, its address must be recovered. In a dynamic network, the head nodes, normal nodes, and proxy nodes will send addr_leave packets to notify neighbor nodes within one hop before leaving the network. The neighbor node that receives the addr_leave data packet will immediately send back the addr_hello data packet to the leaving node. The disconnected node will theoretically receive the reply information from all neighbor nodes, and send the addr_ok data packet to the first replying node. The data packet contains its own address information, and the nearest node will be notified through the data packet. At the same time, after the disconnected node receives the first reply, it stops receiving information and cannot continue to receive addr_hello packets from other nodes.

5 Experiment Analysis

The experiment uses OPNET Modeler as the simulation platform to simulate and analyze the proposed binary tree address allocation, and compare it with the DAAM address configuration scheme, mainly based on the aspects of the average overhead of address configuration and the success rate of address configuration. The nodes are randomly and evenly distributed in the simulation area of 200 m * 200 m square area. The network is divided into 8 network grids, that is, the ordinate and abscissa of the node occupy 2 bits respectively. The value of the number of nodes N is 40, 50, 60, 70, and 80 (Figs. 5, 6 and 7).

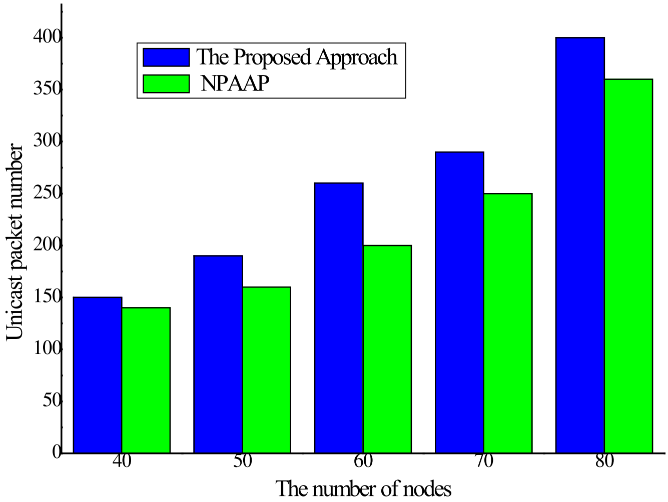

Fig. 5. Unicast overhead comparison chart

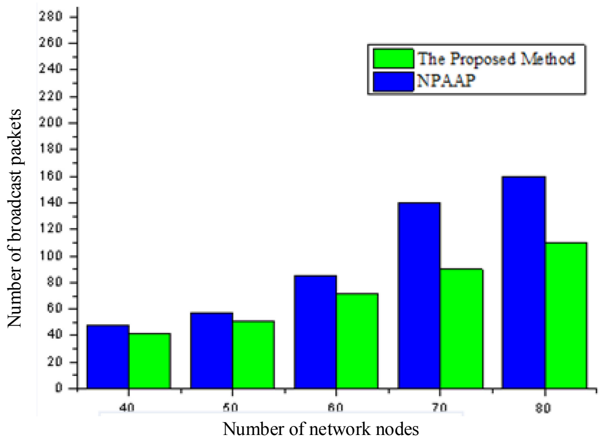

Fig. 6. Broadcast cost comparison chart

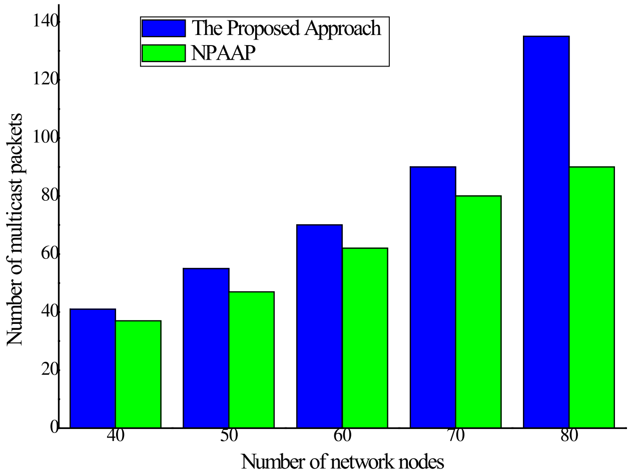

Fig. 7. Multicast overhead comparison chart

In the 6LoWPAN network, nodes within the communication range of this node can communicate directly, and nodes not within the communication range need to be forwarded by an intermediate node. The unicast propagation method is only carried out between two nodes, the multicast propagation method is that multiple nodes participate, and the scope of the broadcast is all nodes in the entire network. In the entire address configuration process, there are unicast and multicast, and broadcast transmission methods. In order to comprehensively compare and analyze the performance of the proposed solutions, the broadcast overhead, unicast overhead and multicast overhead of the NPAAP and the address configuration process proposed in this paper are compared and analyzed. The main statistical method is to set global variables during address configuration. Each time a type of data packet is sent, the number of corresponding information packets is increased.

Compared with NPAAP, the binary tree address configuration scheme proposed in this paper is mainly unicast overhead and multicast overhead. First, the network is divided into network grids based on location information to achieve clustering. Therefore, address configuration is performed in each grid, and there is almost no network-wide broadcast overhead. The new node only sends multicast packets to neighboring nodes within one hop when it joins the network and when the node leaves the network. If there is no free address within one hop, the node will expand the range of sending address requests. Therefore, only a limited number of multicast data packets are generated. At the same time, the range of multicast packets is generally limited to each grid. Although the number of multicast packets is large, the overhead of each multicast data packet is smaller than NPAAP. In addition, new nodes choose proxy nodes for themselves, which are generally close to them, so unicast overhead is also reduced compared with NPAAP.

6 Conclusion

In the binary tree address configuration mechanism studied in this paper, the proxy nodes in the grid usually obtain the corresponding address space automatically according to the number of IP address nodes in the vicinity that have not yet been allocated. This greatly reduces the failure probability of address configuration due to uneven node distribution, and thus reduces the frequency of starting the address borrowing mechanism, which decreases the consumption of address configuration to a certain extent. At the same time, the task of address configuration is assigned to the vast majority of nodes in the network according to a certain mechanism, instead of being concentrated in a small number of nodes, so as to avoid the problem of address configuration failure due to the death of the proxy node. The performance comparison with the traditional address configuration mechanism proves the feasibility of the location information-based address configuration mechanism.

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