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Gateway Research on the Interconnection between Cognitive Network and Ethernet

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Abstract: A network interconnection architecture is proposed, which can realize the interconnection of the protocol stack between the L2 cognitive network and the Ethernet. Firstly, a new addressing method is proposed in L2 cognitive network to represent wireless nodes. Then an address mapping scheme is designed in the gateway, which can realize fast addressing in L2 cognitive network based on IP address, which can solve the serious network redundancy and overhead caused by broadcasting in traditional wireless networks. Finally, an experimental test platform is built, and the feasibility and communication capability of the scheme in the network interconnection system are verified.
Keywords: L2 Cognitive Network; Gateway; Interconnection; Address Mapping; Broadcast.

1. INTRODUCTION

As the third wave of technology development after computer and mobile Internet, Internet of Things(IoT) can be regarded as an extension of the Internet, which can not only extending the traditional interconnection between people and people to people and things, but the interconnection between the things and things[1]. L2 (Layer 2, L2) cognitive network is composed of multiple intelligent terminals with sensing, processing, wireless communication and low power consumption, which can realizes reliable wireless communication between objects in L2/L1 in a self-organizing manner, and the network is able to monitor physical phenomena and environmental conditions through a close connection to the real world.In the L2 cognitive network, the wireless node can become a base station relaying signals for other nodes, and can dynamically utilize network resources such as a wireless spectrum and a wireless station; in wireless multi-hop, each data packet uses a dynamically generated path. And the channel used by each hop is also dynamically generated, so that the network resource utilization can reach the instantaneous maximum[2]. For IoT applications, the L2 cognitive network does not exist independently, but is interconnected with an external network to enable remote management, control, and access to nodes under the network, and then achieving large-scale networking of L2 wireless network based on the existed network facilities.

The traditional Ethernet addressing is through the Address Resolution Protocol (ARP) [3], which can obtain its MAC address according to the IP address of the destination host. The source device knows the MAC address of the target device by broadcasting an ARP request containing the IP address of the target device to all devices on the network and receiving an ARP response. However, in a wireless multi-hop network, it is very costly to broadcast all nodes to the entire network, which not only causes serious network redundancy, but also increases network overhead. In order to solve the above problem, we propose an address mapping management mechanism in the L2 Cognitive network, and set an address mapping table in the gateway that implements the network connection, that is, between the IP/MAC address and the networking address/ID of the node. Correspondence, thus enabling fast addressing in L2 large-scale wireless networks.

2. RESEARCH BACKGROUND

With the continuous advancement of mobile communication technologies, many studies have focused on wireless bandwidth access. Therefore, the main content of research on wireless sensor network (WSN) and Ethernet interconnection is to study the fusion of WSN and TCP/IP protocol [4]. At this stage, there are three main methods for the convergence between TCP/IP and WSN: Peer to peer, overlapping coverage, and full IP.

The Peer to peer method is to set up an Internet gateway between heterogeneous networks, and perform protocol conversion between the WSN and the same protocol layer of the Ethernet, thereby implementing interconnection between two different networks. According to the protocol level of the work, the Internet gateway can be further subdivided into a Network Address Translation (NAT) gateway and an application gateway. The NAT gateway adopts the address-centric private network layer protocol in the WSN, and adopts the standard IP protocol in the Ethernet. The NAT gateway completes the protocol conversion between the WSN and the Ethernet at the network layer, which is implemented in the literature [5]. The application gateway [6] is used to set up a server proxy between different networks. Since the proxy server works at the application layer, it is often called an application gateway. When WSN and Ethernet adopt different protocol stacks, they are implemented by overlapping coverage. The networks are interconnected by protocol bearer instead of protocol conversion. There are two types of coverage between WSN and IP networks. The first type of coverage is Ethernet coverage WSN: [7] proposes a method u-IP for implementing IP protocol stacks on WSN nodes. In this method, Ethernet hosts can directly access WSNs with IP addresses. Node, but the IP protocol can only be deployed on more capable nodes.

The second coverage method is WSN coverage Ethernet [8]: This method is similar to accessing a private network through a VPN (Virtual Private Network) [9] on an IP network. The Ethernet host can be considered a virtual sensor device by deploying the WSN protocol stack over the TCP/IP protocol,. The Ethernet host can communicate directly with the WSN node and can process the packet as well as the WSN node. However, the shortcoming of this method is that an additional protocol stack needs to be deployed on the host of the Ethernet.

The full IP method [10]-[12] is to directly use the TCP/IP protocol stack in the WSN. This method requires each common WSN node to support the IP protocol, and the Ethernet and WSN need to adopt a unified network layer protocol to realize the interconnection.

Based on the previous research work, a Peer to peer method is proposed to realize the interconnection between the L2 cognitive network and the Ethernet. At the same time, the address mapping table is set in the gateway, which not only uses the unicast method for addressing in the wireless multi-hop network, but supports the broadcast addressing in the Ethernet well.

3. GATEWAY SYSTEM DESIGN

3.1 Application scenarios

The application of the Internet of Things covers environmental protection, industrial monitoring, smart home, car networking and other industries. Taking the application of micro-environmental information (temperature, relative humidity, PM2.5, light intensity, ultraviolet light) as an example to illustrate the role of the gateway in the network interconnection. The gateway interconnects a plurality of node devices integrated with the micro-environment sensors to form an L2 cognitive network for collecting micro-environment information. Within the network, the nodes communicate with each other by means of wireless multi-hop; on the other hand, the L2 cognitive network is connected to the external network through the gateway, and the gateway provides an access interface of the external network. In addition, the gateway integrates a 3G/4G communication module and the Internet to connect to an external network. In this way, the remote server can access and supervise all nodes in the L2 cognitive network through the gateway anytime and anywhere.

3.2 Functional requirements

Based on the IoT application scenario, the gateway that implements the cognitive network and Ethernet interconnection should support the cooperation and aggregation of data in the L2 cognitive network and the data transmission between the Ethernet/4G network. Therefore, the design requirements of the gateway are as follows [13]-[14]:

Data Forwarding: The basic function of the Internet gateway is to receive data from a WSN node or Ethernet host and forward the data to another network correctly.

L2 protocol conversion: The L2 cognitive network can adopt the IEEE 802.15.4/Zigbee air interface, and the air interface of other wireless systems can also be used, and the traditional TCP/IP protocol is used in the Ethernet. The sensor data acquired by the gateway from the L2 cognitive network needs to be sent to the Ethernet through other interfaces. Therefore, the gateway needs to analyze the sensing data by the L2 protocol, and then encapsulate and send the sensing data according to the requirements of the Ethernet protocol.

Management and Control: In addition to receiving and forwarding data from Ethernet and WSN nodes, the gateway shall support management and control of WSN nodes. For example, when the gateway receives a command from a remote server, it should be able to process the command and then send it to the sensor node so that the remote device can remotely manage and control the WSN node through the gateway.

3.3 Protocol interconnect architecture

Different from the OSI (Open System Interconnection, OSI) reference model in the traditional Internet network, the L2 cognitive network architecture conforms to the Embedded Wireless

Interconnect (EWI) reference model [15], which satisfies the concept of cognitive network. The protocol stack of the wireless node and gateway in the L2 cognitive network is shown in Figure 1.

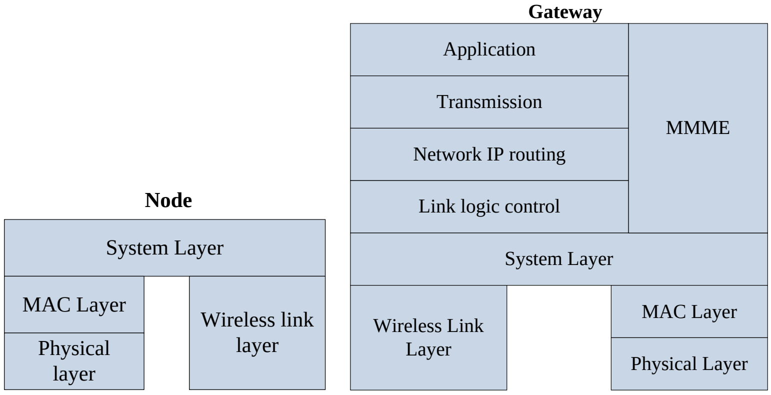

Fig.1 node and gateway protocol stack

Among the nodes constituting the L2 cognitive network, the MAC layer and the physical layer are access networks, and the system layer bridges the access network and the backhaul network; in the gateway, the system layer can implement protocol conversion between the L2 cognitive network and the Ethernet to achieve seamless user roaming. The system layer is located below the logical link control layer, and the MAC layer and the physical layer are cable/fiber based Ethernet connections. Therefore, the system layer in the gateway bridges the backhaul network and Ethernet. In addition, since there is no network layer in the node, the node can be regarded as an L2 exchange from the IP site [16]-[17]。

In L2 cognitive networks, user mobility management can be implemented by protocols in nodes and gateways. User roaming can be L2 roaming (link layer) or L3 roaming (network layer). When the mobile users are in the same IP subnet but switch to different access points, they belong to L2 roaming; when the mobile users move within different IP subnets and change their IP addresses, they belong to L3 roaming.

In the gateway, the MMME (Macro Mobility Management Entity Macro Mobility Management Entity, MMME for short) is used to implement soft handover in L3 roaming. MMME is an application layer proxy, but it is also directly connected to the system layer. When a mobile user enters a new IP subnet, for example, by receiving a route advertisement broadcast from the new gateway, the user will attempt to obtain a new IP address and other service level configuration, such as via DHCP (Dynamic Host Configuration Protocol).

The request is forwarded directly to the MMME after translation by the system layer. Then, the MMME authenticates the mobile user by consulting a service provider server on the Internet (for example, through Authentication, Authorization, Accounting, or AAA), and then assigning a IP address for new mobile user. Then, the MMME of the current gateway sends a message to the MMME of one gateway through TCP/IP, and the previous gateway stops serving the mobile user after receiving the message. Since the old IP address still works with the previous gateway during the handover process, soft handoff can be implemented in L3 roaming.

3.4 L2 Networking address configuration

Due to the limitation of energy consumption and bandwidth, it is very important to reduce or even avoid the redundant transmission of network overhead caused by the broadcast algorithm in the L2 cognitive network, especially when the network scale is large and the nodes in the network are deployed densely. In order to solve this problem, a new L2 networking addressing method is proposed in the L2 cognitive network to characterize the wireless node, and an address mapping scheme is designed in the gateway, and addressing in the L2 cognitive network based on IP addresses is achieved by configuring the wireless node with a networking address [18]-[19].

In the experiment, the networking address of the L2 cognitive network consists of 3 bytes, which are configured by the host through configuration software or dynamically configured through network neighborhood information. The first byte contains the network ID (first two bits) and the node ID (the last six digits), and the second byte and the third byte represent the coordinates of the node in the network respectively. The Manhattan distance d between any two nodes m and n can be expressed as: $d = |X_m - X_n| + |Y_m - Y_n|$, where X_m and Y_m are the last two bytes of the network address of the node m, and X_n and Y_n are the last two bytes of the network address of the node n. Under the same network ID, the Manhattan distance between any two nodes is related to its mutual RSSI (Received Signal Strength Indication). The larger the RSSI , the smaller the Manhattan distance.

In the L2 cognitive network, a unicast packet can be sent from the sending node (pre-hop relay or source node) to the candidate relay node if any of the following conditions are met:

The source node is different from the network ID of the target node, and the relay has the same network ID as the target node;

The source node, the relay node and the target node share the same network ID, and the Manhattan distance between the source node and the target node is greater than the Manhattan distance between the relay node and the target node.

3.5 Address mapping mechanism

In the L2 cognitive network, the L2 networking address and IP/MAC address are used to represent the wireless node. When the node accesses the network, the information registration needs to be performed at the gateway, including the networking address and IP/MAC address of the node. At this time, the gateway maintains a mapping table of the networking addresses and IP/MAC addresses of all the wireless nodes in the network, that is, an address map (abbreviated as addrmap), and its contents are shown in Table 2. The ARP broadcast packet from the Ethernet, the gateway may choose to directly reply to the ARP request, or forward the ARP packet to a specific node in the network; for packets from Ethernet, the gateway can look at the addrmap table and forward the packet to the appropriate destination node over the L2 cognitive wireless multi-hop network.

Table 1 Node registration message format to the gateway

Octets	Fields	Description
0	0	Protocol version
1	0x07	Report of belonging
2	0x02	Message type
3	14	Message length
4-5	Sequence Number	serial number
6-8	Target Network Address	Target node networking address
9-11	Source Network Address	Source node networking address

12-13	CRC	Check code

Table 2 Contents of addrmap

Network address	IP address	MAC address
3 bytes	IPv4 or IPv6	6 bytes

The purpose of establishing an address mapping mechanism in the gateway of the L2 cognitive network is to avoid packet redundancy and large network overhead caused by broadcast addressing in large-scale wireless multi-hop networks. The following takes the Ethernet and L2 cognitive network between the two hosts in Figure 2 as an example to describe the address mapping mechanism in the gateway.

The terminal initiates an ARP request packet to the host, and the source IP address and MAC address carried by the ARP request packet sent from the terminal are respectively the IP address and MAC address of the terminal. Since the MAC address of the host is unknown to the terminal, the ARP request packet only contains the IP address of the host, and the ARP request packet is first received by the gateway1 connected to the terminal through the Ethernet;

After receiving the ARP request packet sent by the terminal to the host, the gateway1 first registers its own network address and the host's IP/MAC address in the address mapping table of the networking address and IP/MAC address of the gateway2 through the L2 wireless mode;

The gateway2 records the mapping relationship between the networking address sent by the gateway1 and the IP/MAC address in the address mapping table;

The gateway1 sends the received ARP request packet sent by the terminal to the host to the gateway through the L2 wireless network;

After receiving the ARP request packet sent by the terminal to the host, the gateway changes the MAC address of the packet to the MAC address of the gateway itself, and the IP address remains unchanged, and records the network address of the packet, and then send it to the target host through Ethernet;

The host responds normally to the ARP request packet from the terminal; the source IP address and the MAC address carried in the ARP request packet are respectively the IP address and the MAC address of the host, the destination MAC address is the MAC address of the gateway 2, and the IP address is the IP address of the terminal;

After receiving the ARP response packet of the host, the gateway queries the previously registered address mapping table according to the IP address in the ARP response, finds the network corresponding to the IP address, and then sends the ARP response packet to the gateway1 through the L2 wireless network;

After receiving the ARP response packet sent by the gateway2, the gateway1 changes the source MAC address of the packet to the MAC address of the gateway1, and then sends the packet to the terminal device through the Ethernet;

The source MAC address carried in the ARP response packet received by the terminal from the host is actually the MAC address of the gateway1 connected to the terminal, so that the Ethernet packet sent to the gateway1 through the terminal can be received by the gateway1. and the Ethernet packet is then sent to the wireless communication interface of the gateway2 through the wireless communication interface of the gateway1, and then transmitted to the host through the Ethernet interface.

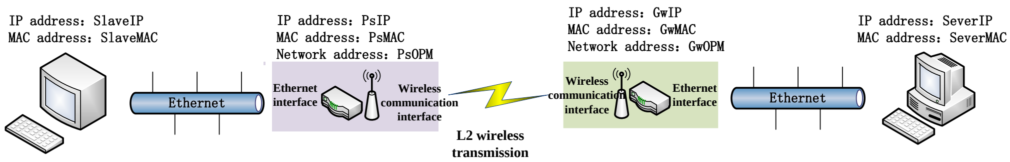

Fig.2 Device connection diagram

4. GATEWAY SYSTEM IMPLEMENTATION

The hardware structure of the gateway is shown in Figure 3. The gateway includes a digital signal controller, an Ethernet controller, a wireless communication module, a power module, etc. The main functions of the gateway include two, one is to read the data sent from the node and forward the sensory data, and the other is to accept the command from the application server and parse the command [20]-[21]. Among them, the gateway realizes interaction with the remote terminal through the Ethernet and the IP protocol stack. Ethernet Interactive sets the socket connection by setting the IP address and listening port of the remote server.

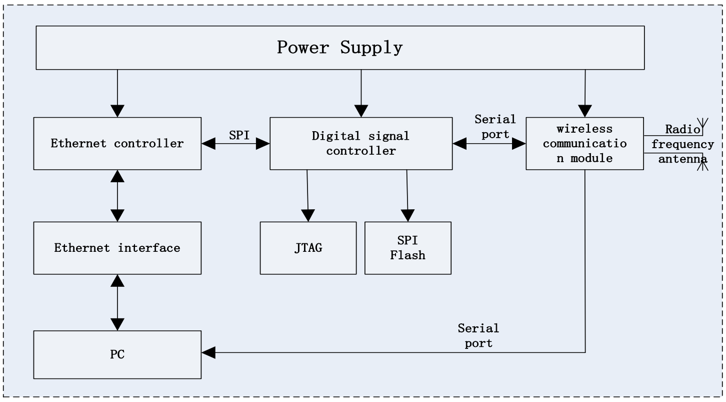

Fig.3 Hardware structure diagram

After the gateway starts, it performs a boot loader operation and flushes it into the firmware as the main program. After all the modules of the device are initialized, their ports start to listen and wait for external events to occur. Once an external event is detected, the main program checks the data type to determine the corresponding response operation [22]. If the interrupt data comes from a remote server, the data is a command, and the main program needs to analyze the data to determine whether the target is a gateway or a node in the L2 cognitive network, and then send the command content to the L2 cognitive network. If the content of the command is to obtain gateway information or a gateway log, the main program calls the interface of the remote server interaction module to send the gateway log and the corresponding parameter information of the gateway to the remote server. If the command object is a sensor node in the L2 cognitive wireless network, the gateway analyzes the command by invoking the interface of the protocol analysis module and invokes the interface of the serial data transceiver to send information to the destination sensor node. If the data comes from the L2 cognitive wireless multi-hop network, the main program analyzes the data by calling the protocol analysis module, and then calls the remote server interaction module to send the sensory data to the remote server. The workflow diagram is shown in Figure 4.

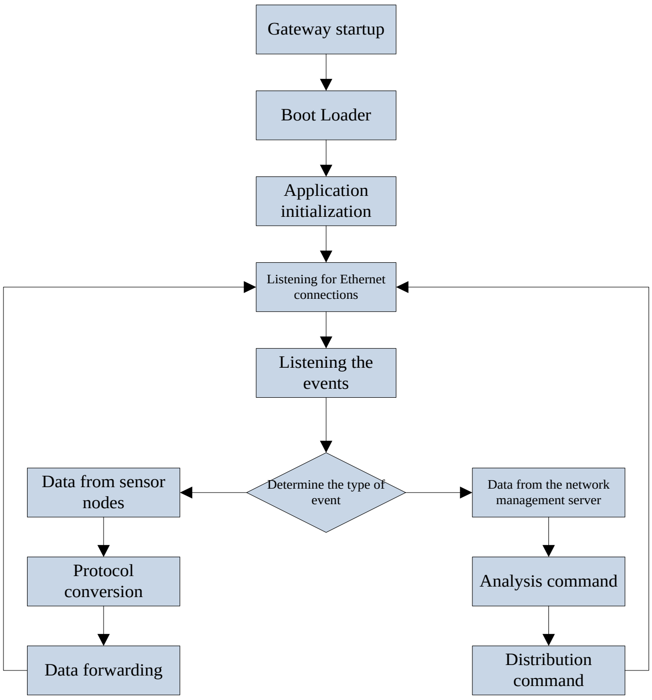

Fig. 4 Gateway workflow

5. EXPERIMENTAL VERIFICATION

In order to prove that the proposed method is feasible and effective, experiments were designed to verify. The equipment included in this experiment has a 4G router, a gateway and two sensor nodes, wherein the gateway and sensor nodes form an L2 cognitive network, and the gateway and the 4G router are connected through Ethernet, to the gateway and sensor nodes and sensor nodes. The communication capabilities is

tested.

The basic information of the equipment required for the experiment is shown in Table 3.

Table 3 Equipment information required for the experiment

Equipment type	IP address	MAC address	Network address
Gateway	192.168.8.103	02.01.41.03.a4.00	41.01.02
Sensor node1	N/A	03.01.41.03.a4.00	41.01.03
Sensor node2	N/A	04.01.41.03.a4.00	41.01.04

First, the communication capability between the gateway and the sensor node is tested, where Packet interval (*50ms)=20, Report interval(*s)=2s.

1). Communication capability test between gateway and sensor node 1

Set the Target Address to 41.01.02 and the Slave Address to 41.01.03. The test results are shown in Figure 5.

Analysis of the results: In multiple measurements, the packet loss rate of the communication data between the gateway and the sensor node 1 is basically zero.

2). Communication capability test between gateway and sensor node 2

Set the Target Address to 41.01.02 and the Slave Address to 41.01.04. The test results are shown in Figure 6.

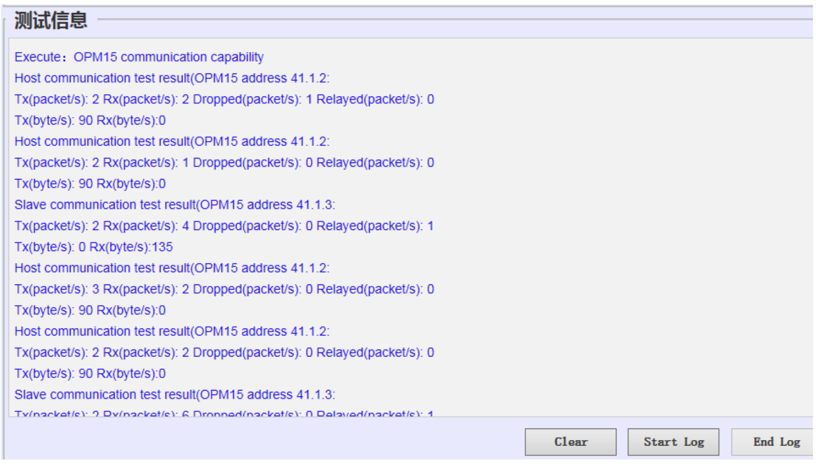

Fig.5 Communication capability test between gateway and sensor node 1

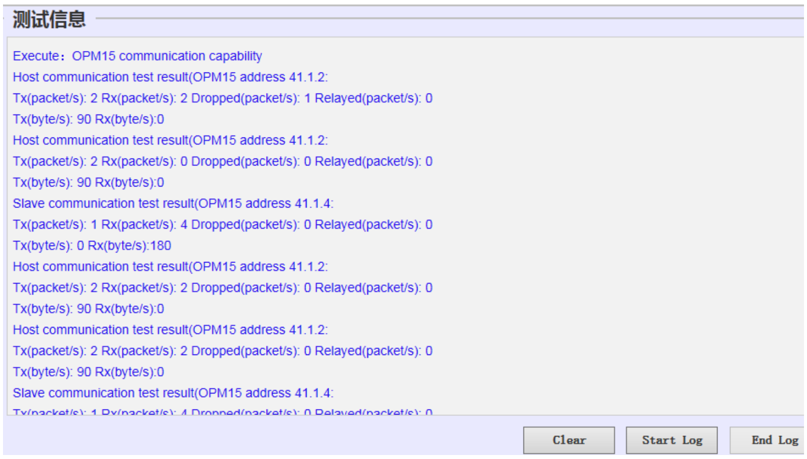

Fig.6 Communication capability test between gateway and sensor node 2

Communication capability test between sensor node 1 and sensor node 2

Set the Target Address to 41.01.03 and the Slave Address to 41.01.04. The test results are shown in Figure 7.

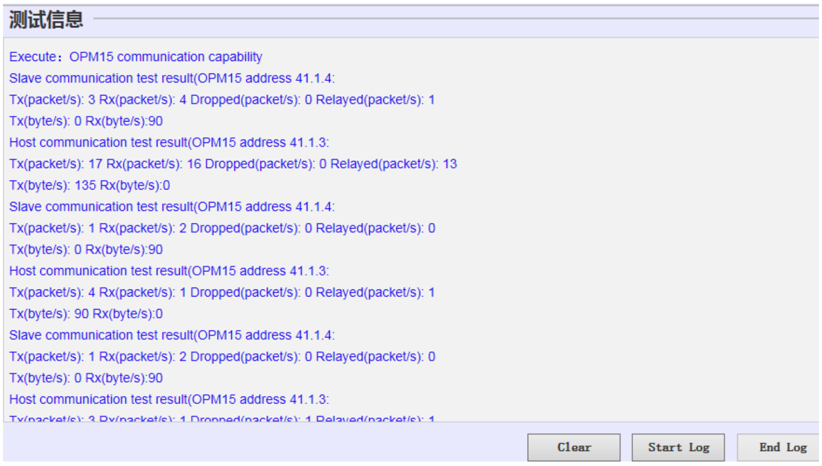

Fig.7 Communication capability test between gateway and sensor node 1

Analysis of results

It can be seen from the results of FIG. 5 to FIG. 7 that in the L2 cognitive network, the communication packet loss rate between the gateway and the sensor node and between the sensor nodes is basically zero, which proves that the gateway system has stable performance and has a very high reliability.

6. CONCLUSION

Cognitive networks have broad application prospects in the field of Internet of Things. Nodes in the network implement self-organizing networks through wireless multi-hop, and can interact with remote servers through gateways. A new addressing method is proposed to characterize the wireless node through the L2 networking address and physical address. In addition, setting the address mapping table in the gateway can avoid broadcasting in a resource-limited wireless multi-hop network, thereby reducing data redundancy and network overhead, thereby ensuring good feasibility of the entire network.

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