



IP Addressing and Address Management of Space-Based Network Based on Geographical Division

Fu Wei^{1(✉)}, Xu Zhen¹, and Gao Zihe²

¹ School of Electronic and Information Engineering, Beihang University, Beijing 100191, China

fuwei@buaa.edu.cn

² China Academy of Space Technology, Beijing 100094, China

Abstract. In this article, a detailed geographically-based address allocation method in space-based network is designed, which saves address resources, reduces the size of routing tables, and improves data forwarding efficiency. On this basis, an address management method is proposed to reduce the impact of satellite handover on data transmission. The simulation results of the model on the simulation platform show that our address management method can automatically assign addresses and achieve efficient routing addressing. The handover between a satellite and location areas does not affect the terminal node.

Keywords: Space-based network · Addressing · Satellite handover

1 Introduction

The space-based network mainly refers to a network that uses satellites as an access point to provide communication for the ground. It is the main way and method for collecting, processing, and forwarding information or resources obtained in space. It is regarded as an important part of the next generation Internet by many domestic and foreign enterprises and units. Due to the convergence trend of space-based networks and terrestrial Internet, it is necessary to directly use IP protocol in space-based networks to enhance compatibility. In addition, as the cost of terrestrial access terminals decreases, the number of access terminals will continue to increase. Therefore, it is necessary to consider how to better allocate and manage the IP addresses of access users.

Specifically, address allocation management in the network mainly includes two addressing ideas: host-based and link-based. The former is to directly assign an address to a host in the network. The advantage is to save address resources, but it will make the routing table size of the nodes in the network increase linearly with the number of nodes, which in turn leads to an increase in calculation and search. [1] The latter is to configure the address for the host's interface. The advantage is that for the router, only the subnet information aggregated by the gateway node needs to be stored, which greatly improves the routing lookup efficiency. However, the mobility of satellite nodes will cause link periodic disconnection, making this method couldn't be directly applied

to the space-based network. [2] According to the existing routing table entry measurement research [3], the main reason for the continuous growth of the routing table is that the aggregation relationship cannot be maintained and the network address fragmentation is excessive. Therefore, the key to addressing space-based networks is how to maintain the hierarchical relationship in the network and realize the aggregation of subnets. A method for segmenting the network based on the ground coverage area of the low-orbit satellite provides idea for how to maintain the hierarchy of nodes in the network during addressing. Although this addressing method has been preliminarily studied, there are still many details that are not perfect for address management and specific implementation [4]. No consideration has been given to the address allocation of the space-based network during deployment, nor the address and link changes caused by the movement of satellite nodes and ground user nodes in the space-based network. Therefore, this article will carry out further research on the IP address management method of space-based network based on geographical division.

The main work of this paper is as follows: in section two, we designed the IP address allocation method of space-based network based on geographic partitioning. This method divides the earth's surface into multiple regions and location areas based on network structure and geographic information. According to the mapping relationship between the partition and the satellite node, we improve routing addressing method, reducing the number of routing table entries. In section three, we propose link and IP address handover management method in space-based networks. By preprocessing before the satellite's corresponding location area changes, the terminal information remains unchanged, thereby ensuring that the terminal address within the area remain unchanged. The timing of switching is determined by the terminal, which reduces the impact of link switching on data transmission. Finally, the space-based network architecture is modeled on the simulation development platform, and joined the ground access terminal to test whether the handover management is realized. We also make the simulation output visualized. Simulation results show that for space-based networks, this address management method can automatically assign addresses, achieve routing addressing, avoid the occurrence of abnormal access terminals, and the handover between satellite and location area will not affect terminal nodes.

2 IP Addressing and Allocation

To achieve better ground coverage, higher communication rates, and lower access delays, the development of a global mobile satellite network based on a low-orbit satellite network has become an international military and civilian satellite system development trend. For a single country, due to geopolitical factors and defense security considerations, satellite ground stations cannot be evenly deployed globally. Therefore, by increasing the number and performance of geostationary satellites, a more space-based network can be created.

2.1 Network Architecture and Addressing Concept

For the purpose of better explaining our addressing concepts and methods, a space-based network model with a three-layer network structure is proposed. The convergence layer node is composed of dozens of satellites running in geostationary orbit, and serves as the main bridge between the space-based network and the ground network. The access layer node is composed of hundreds of low-orbit satellites to provide data transmission capabilities for ground access terminals. The ground network layer is composed of interconnected ground stations and data centers to achieve the connection to the Internet, and is connected to the satellite nodes of the convergence layer by satellite-ground links. Through the interconnection of the ground core network with the Internet and cellular communication networks, the integration of the satellite-ground network can be achieved to meet the needs of commercial and military data access (Fig. 1).

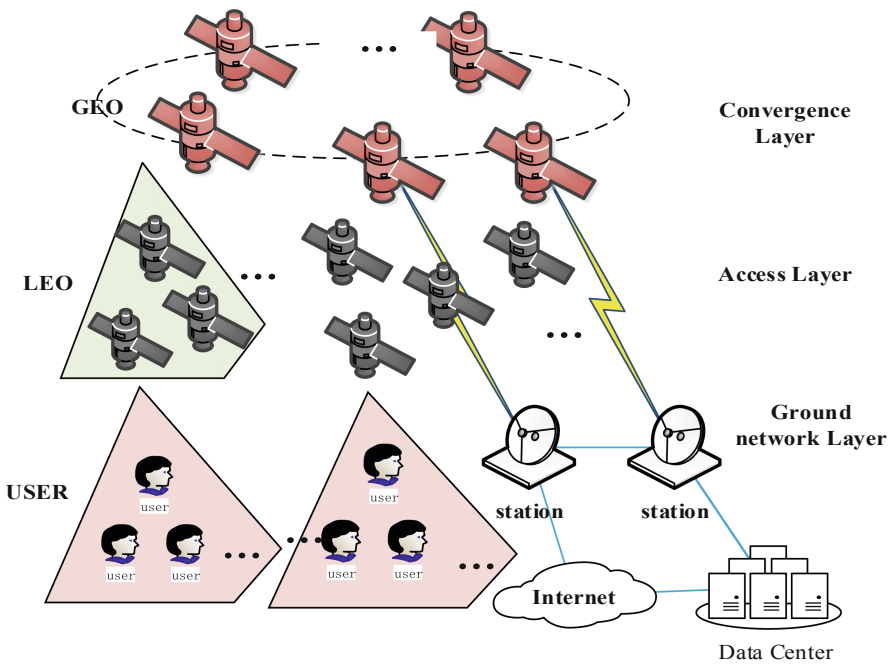


Fig. 1. Space-based network architecture

The network layer is the key to realize the integration between heterogeneous networks. Using IP addressing format is the mainstream method to avoid increasing the redundant traffic due to conversion of address formats. Besides, a unified address allocation method can also improve the throughput and efficiency of data exchange between the stars and the ground. In the network layer, since the existing Internet still widely uses the IPv4 protocol, IPv4-in-IPv6 [5] related tunneling technology has also

been studied, which means IPv4 format addresses will easily evolve into IPv6. In the IPv4 protocol, the identifier set for each user consists of 32 binary digits, which can distinguish up to more than 4 billion user terminals.

In order to achieve the aggregation of subnet addresses, for a given IP address segment, we divide it into many subnets that can be aggregated, and then assign the subnet to each ground area [6]. For a low-orbit satellite constellation with P low-orbit satellites orbiting planes and S nodes in each plane, the earth surface coverage area can be divided into $M = P \times S$ ground location areas. Each location area corresponds to a satellite at the same time. In addition, the location areas of the same longitude are aggregated into a region, which means that there will be P regions. The geostationary satellite selects its own service area according to its longitude and traffic of the region, and establishes an inter-satellite link with the low earth orbit (LEO) satellite node corresponding to the location area in the region. This method combines link-based and host-based addressing features, which improves routing addressing efficiency through address aggregation and reduces the required address space.

2.2 Address Allocation

The links in the space-based network can be divided into inter-satellite links and satellite-ground links according to different types of nodes, and also can be divided into point-to-point links and spot beam links according to the number of nodes. Our address allocation method will allocate addresses in the order of allocating the satellite-ground link subnet first and then the inter-satellite link subnet (Fig. 2).

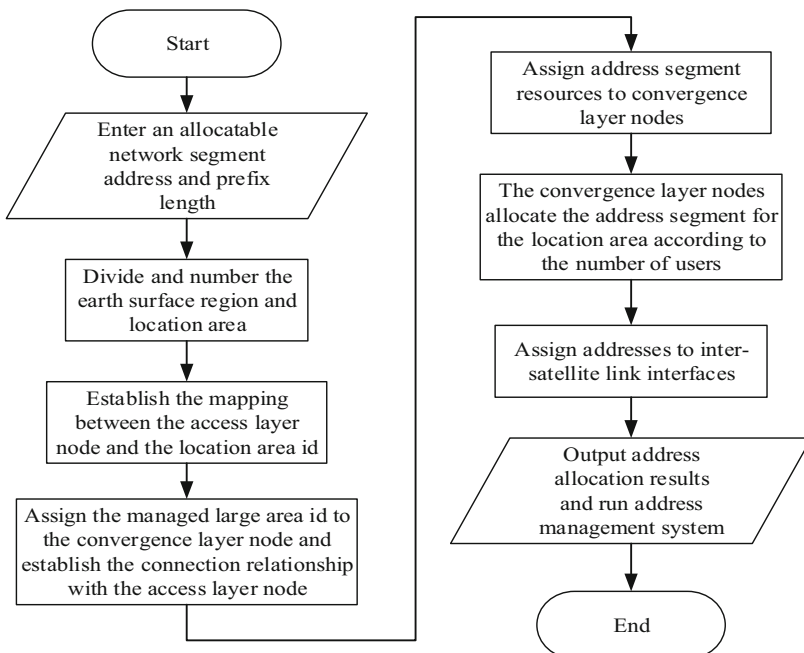


Fig. 2. Main process of IP address allocation

The first step is to divide the given network segment into aggregated subnets. Our project adopts classless addressing scheme which uses variable-length subnet mask (VLSM), and implements address aggregation through classless inter-domain routing (CIDR) [7]. In this method, the network type and network number no longer restrict the address format, and the subnet size can be changed to any size [8]. According to the hierarchical relationship in the space-based network, the address segment is firstly divided into different subnet segments according to the number of regions. Then the subnet segment is subdivided again according to the number of ground location areas.

After completing the division of the subnet, we begin to assign addresses to the satellite-ground links. The interface communicating to ground of the access layer node will be assigned the first IP address of the corresponding subnet segment. The ground access host finds its ground location area, registers in the location area and obtains a host address. The address of the access host when it first accesses the service location area is assigned by the satellite node. According to RFC 3927, the host can choose an address from the 169.254.0.0/16 address segment as a temporary IP address for the initial address application and terminal registration [9].

Then, the address allocation of the inter-satellite link is performed. The subnet mask of a point-to-point inter-satellite link in space can be expressed as 255.255.255.252, indicating that the link can accommodate two interface addresses in addition to the network address and broadcast address, corresponding to the two ends of the link. Therefore, a single point-to-point inter-satellite link needs at least 4 addresses. We divide the links into permanent links and dynamic links according to whether they will change. Since the permanent links are all point-to-point links in the space-based network, the interface addresses of both ends can be directly configured as a subnet, such as 172.22.1.5 and 172.22.1.6, the addresses should be applied for F permanent links can be expressed as:

$$N_{perm} = \sum_{i=0}^F f_i = 4F \quad (1)$$

For dynamic links between satellite nodes with different orbit radii, the link subnet address is assigned to the interface of the node with a larger orbit radius, making it the party which actively allocates the address (referred to as the active party), the other address of the interface is dynamically allocated by the active party. If the high-orbit node is a point-to-multipoint link of the spot beam type, the number of addresses required for a group of links with a maximum of d nodes is:

$$n_{dyna} = 2^K \geq d + 2, K \in N \quad (2)$$

For satellite nodes with the same orbit radii, although the inter-satellite links are all point-to-point links, the node links between different orbital planes will be disconnected or switched due to the latitude of the node. According to the id of the track plane, the link subnet address is assigned to the interface with the higher track plane id, and another interface is not assigned an initial IP address. When the dynamic link is established, the party with the address sends its own address, and the party without the

initial address first selects a temporary address from the 169.254.0.0/16 address segment as the communication address.

Therefore, the number of addresses required by D dynamic links and the total number of addresses of inter-satellite links are:

$$N_{dyna} = \sum_{i=1}^D n_{i-dyna} \quad (3)$$

$$N_{ISL} = N_{perm} + N_{dyna} \quad (4)$$

2.3 Routing Strategy

After accessing the ground location area and applying for an IP address, the ground node can communicate with other nodes in the space-based network or the server in the Internet through the ground network nodes, so the data packets transmitted in the network need to be routed, addressed, and determined the egress interface corresponding to the next hop according to the destination address of the packet. Since only the ground network nodes and the access terminal nodes can send and receive data in the network, other satellite nodes will only forward data packets, and will not generate a lot of application layer information. Therefore, the routing addressing method should target the data packets sent by ground users. In space-based networks, terrestrial user terminals must have a home location area. Through the mapping of the location area and satellite nodes, the data packets will eventually be routed based on the satellite nodes. This method has less cost and higher routing performance, and is more suitable for space-based networks with multiple nodes [10].

Each satellite node has three processing steps for the received data packets:

1. Find the number information of the region and ground location area to which it belongs according to the destination address of the received data packet;
2. Search for the corresponding satellite node in the mapping table between the satellite node and the service location area, according to the number of the ground location area;
3. If the corresponding node is the current satellite node, the ground terminal information is queried and sent to the corresponding terminal; otherwise, the corresponding next hop exit is searched in the node routing table according to the satellite node information, and the data packet is forwarded.

The routing information between the satellite nodes can be calculated and converged by itself at the initial stage of the establishment of space-based network. By mapping the destination address to a specific satellite node, our routing method shields the addressing difficulties caused by link switching, reduces the cost of routing maintenance, and is more suitable for the long-term operation of space-based networks.

3 IP Address Management and Handover

3.1 Address Management of Inter-Satellite Link

Due to the different orbit radii, inclination and phase of the satellite, the inter-satellite link will dynamically switch. Inter-satellite links are mainly composed of links in the same orbital plane, links in adjacent orbital planes and links in different orbital radii, where dynamic links mainly exist between nodes in different orbital planes or orbital heights. If the nodes on the link have the same orbit radii but different orbit planes, address management is performed according to the orbit id, as shown in the following figure. The node with the higher orbital plane number where the node is located manages the address, and the interface of the other party obtains the communication address through the handshake information when the link is established, and resets its interface address after the link is disconnected (Fig. 3).

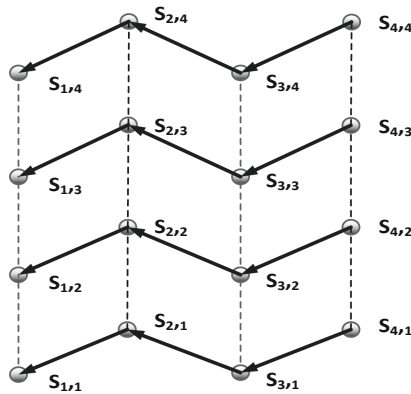


Fig. 3. Address management of links between adjacent orbit planes

For link handover between satellite nodes with different orbit radii, address management is performed according to the operating altitude and the level in the space-based network. For the node interface that may establish a connection, the node closer to the ground network manages the address. For example, when establishing a link with an aggregation layer node, the access layer node selects the aggregation layer node bound to the region for handshake according to the correspondence between the ground location area and the region, and the aggregation layer node allocates the address to ensure its own interface. The interfaces corresponding to the aggregation layer nodes are in the same subnet. When the access layer node leaves the area, the link is disconnected, the convergence layer node reclaims the assigned address, and the access layer node interface resets the address to zero.

3.2 Address Handover of the Satellite-Ground Link

The satellite-ground link is mainly composed of the connection between the satellite node and the ground station or the ground access terminal. Since the geostationary satellite is stationary relative to the ground, the satellite-ground link of the ground station will generally not switch. During the operation of the space-based network, as shown in the following figure, the LEO node moves relatively faster than the ground, so the coverage area is also constantly changing. Therefore, we need perform address maintenance for the interface of LEO node connected to the ground access terminal. In order to better distinguish different satellites and their orbits planes, so as to more concisely represent the mapping relationship between satellites and location areas, the LEO nodes are numbered uniformly. Eventually, routing and address management are performed through the correspondence between satellite id and location areas (Fig. 4).

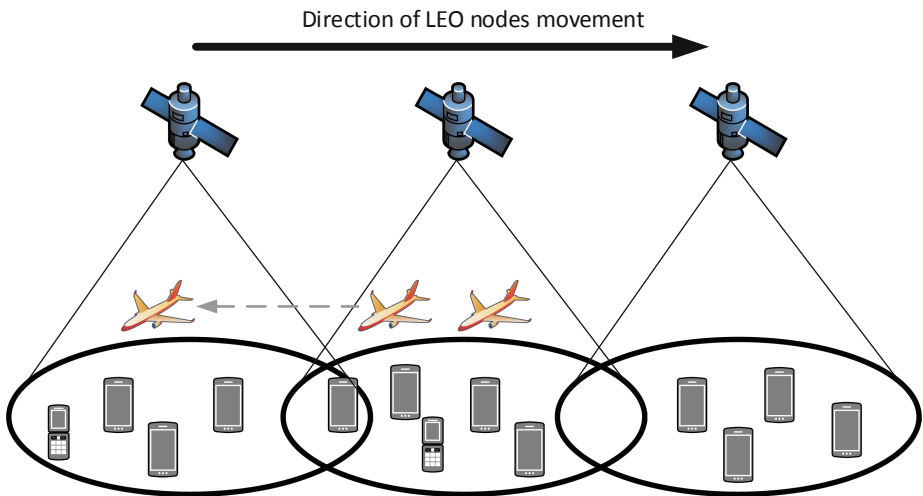


Fig. 4. Movement of LEO nodes

If the LEO's interface initiates link handover and updates the interface address, it will result in a large number of simultaneous interruption of the user terminal's link, affecting data transmission and upper-layer application sessions. Therefore, in order to better ensure that the LEO node smoothly switches the ground-based location area, we consider adding an interface of LEO to ground. One of the interfaces serves the current location area, and another interface forwards the data packets of the adjacent location area. The location area served by the satellite node is simply referred to as the service location area, the forwarded adjacent location area is called the proxy location area, the satellite bound to the ground location area is called the service satellite, and the satellite that forwards the specific location area grouping is called the proxy satellite.

For a location area A, the binding and handover process of its serving satellite is shown in the flowchart. Initially, the relationship between the serving satellite and the location area is determined according to the location information of the satellite node, and then it is periodically checked whether the handover process starts. The average coverage period of the satellite to the location area is obtained through dividing the time of satellite circling the earth by the number of location areas under the orbital plane. The average coverage period of the low-orbit satellites in the same orbital plane is equal. When the location area is served for more than a certain time, the satellite nodes in the same orbital plane start the switching process at the same time, making the rear satellite as the proxy satellite node, which will serve as the new service satellite in the future. Then the current service satellite sends main information of the location area, including geographic location, network resources, and information of connected users to the proxy satellite. At the same time, the current satellite will also broadcast to the connected terminal, indicating that the handover is about to occur, and the ground terminal will decide whether to switch to the new satellite.

On the one hand, if the ground user does not choose to switch at this time, then its address and the address of the opposite end of the link will not change, maintaining the original data transmission. When the service time of the current satellite reaches the average coverage period, the satellite node performs the conversion from the service role to the proxy role. The current satellite no longer serves as the location area's service node, and the user terminal information is no longer updated. However, for the terminals still connected, the satellite will act as proxy node and forward the sent data packets to the new service node.

On the other hand, after receiving the handover start message from the original satellite node, the rear satellite begins to initialize its own proxy information, records the registered ground terminal and select a free address to configure another interface from the network segment of the location area. To avoid conflicts, the interface addresses of proxy and service satellite are reserved from the network segment of the location area, which means the first two addresses can be allocated in the network segment. Then the new satellite node configures its own forwarding strategy and officially becomes the proxy satellite in location area A. After receiving the formal handover message, the new satellite changes the forwarding strategy again and becomes the serving satellite in location area A. The processed data packets are searched in the access terminal information table in location area A according to the routing strategy in Sect. 3 (Fig. 5).

In order to keep the satellite nodes in each orbital plane switching synchronously, the nodes need to broadcast their status of service or proxy to neighboring nodes in the same orbit every short period of time. Through this "heartbeat" mechanism, satellite nodes and service location areas can maintain their correspondence relationship, try to reduce the delay caused by handover, and keep it consistent in all low-orbit satellite nodes, so as to ensure normal routing addressing.

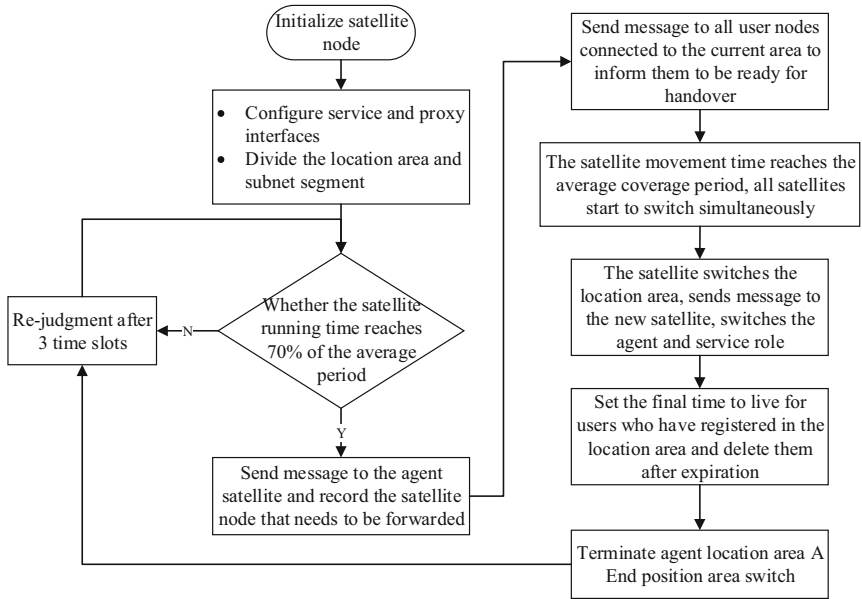


Fig. 5. Process of satellite handover

4 Network Simulation and Visualization

4.1 IP Addressing and Address Allocation Simulation

To simulate our space-based network model, we built a space-based network simulation platform, the overall architecture is shown in the following figure. The simulation platform is mainly composed of four parts: scene maintenance, address management, data transmission and 3D demonstration platform (Fig. 6).

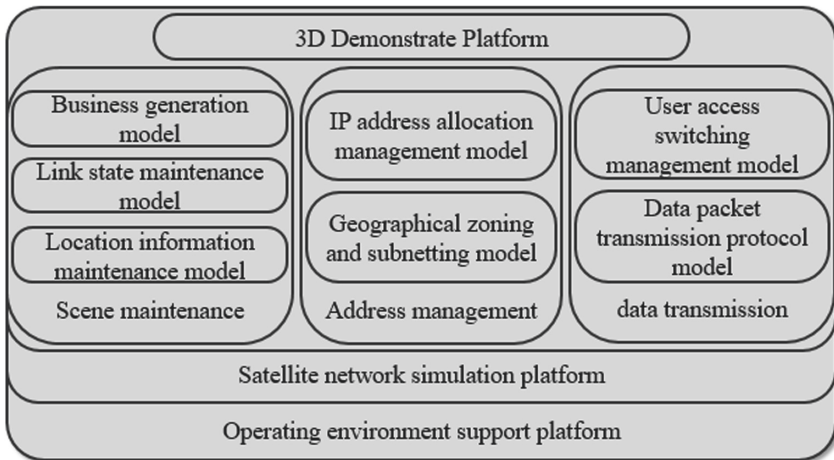


Fig. 6. The overall architecture of space-based network address management simulation

According to actual requirements, the nodes in the space-based network are mainly composed of four types of satellite nodes and three types of ground nodes. The specific number of nodes is shown in the following table (Table 1).

Table 1. Configuration of node in simulation scenario

| Node type | Number of node | Number of interface | Node id in scene |
|------------------|----------------|---------------------|------------------|
| IGSO node | 3 | 3 | 6–8 |
| GEO node | 14 | 6 | 9–22 |
| HEO node | 3 | 3 | 23–25 |
| LEO node | 110 | 6 | 26–135 |
| Ground gate node | 5 | 6 | 136–140 |

With the address 172.22.0.0 and the prefix length of 13 as the specified network segment information, the division of the region and the allocation of address are performed before the scene starts to run. First, the address allocation module will check whether the giving network segment meets the existing space-based network topology requirements and calculate the required number of addresses according to the number of node interface types and the number of links, and then start the division of the location area. According to the number of LEO satellite nodes, the surface of earth is evenly divided by latitude and longitude. According to the number of GEO satellite nodes and Eq. (1), the allocable address segment is divided into $2^4 = 16$ subnets of the same size, and the prefix length of each network segment is $13 + 4 = 17$. Each aggregation layer node selects the nearest one or two regions as its own service area according to its longitude information, and assigns a subnet address segment to each location area according to the location area information in the area. Each region requires $2^3 = 8$ subnets, so the network prefix length of the location area is $17 + 3 = 20$, and finally ensure that each location area can support at least 2046 allocable addresses.

After the subnet division, a specific IP address needs to be configured for each interface. Since the first address of each network segment indicates the subnet itself, the interface of LEO node connected to the ground is assigned the second address. Also, we reserve the third address of the network segment for the proxy interface of LEO node. For address allocation of inter-satellite links in the space-based network, we also follow the relevant design in Sect. 3 to allocate address segments for management interfaces.

We output the main information of each ground location area in the log file for easy viewing at runtime, as shown below (Fig. 7).

```

[INFO][0][Print_Grcells_Basicinfo] leo id, startposi, addrinfo:|
[INFO][0][cell id 0, geo id 11, leo id 134, startposi      -180,      -90, addrinfo 172.23.136.0
[INFO][0][cell id 1, geo id 11, leo id 135, startposi      -180, -57.2727, addrinfo 172.23.144.0
[INFO][0][cell id 2, geo id 11, leo id 125, startposi      -180, -24.5455, addrinfo 172.23.152.0
[INFO][0][cell id 3, geo id 11, leo id 126, startposi      -180,  8.18182, addrinfo 172.23.160.0
[INFO][0][cell id 4, geo id 11, leo id 127, startposi      -180, 40.9091,  addrinfo 172.23.168.0
[INFO][0][cell id 5, geo id 11, leo id 128, startposi      -180, 73.6364,  addrinfo 172.23.176.0
[INFO][0][cell id 6, geo id 18, leo id 129, startposi        0, 40.9091,  addrinfo 172.27.8.0
[INFO][0][cell id 7, geo id 18, leo id 130, startposi        0, 8.18182,  addrinfo 172.27.16.0
[INFO][0][cell id 8, geo id 18, leo id 131, startposi        0, -24.5455,  addrinfo 172.27.24.0
[INFO][0][cell id 9, geo id 18, leo id 132, startposi        0, -57.2727,  addrinfo 172.27.32.0
[INFO][0][cell id 10, geo id 18, leo id 133, startposi        0,      -90,  addrinfo 172.27.40.0
[INFO][0][cell id 11, geo id 12, leo id 29, startposi       -162,      -90,  addrinfo 172.24.8.0
[INFO][0][cell id 12, geo id 12, leo id 30, startposi       -162, -57.2727,  addrinfo 172.24.16.0
[INFO][0][cell id 13, geo id 12, leo id 31, startposi       -162, -24.5455,  addrinfo 172.24.24.0
[INFO][0][cell id 14, geo id 12, leo id 32, startposi       -162,  8.18182,  addrinfo 172.24.32.0
[INFO][0][cell id 15, geo id 12, leo id 33, startposi       -162, 40.9091,  addrinfo 172.24.40.0
[INFO][0][cell id 16, geo id 12, leo id 34, startposi       -162, 73.6364,  addrinfo 172.24.48.0
[INFO][0][cell id 17, geo id 19, leo id 35, startposi        18, 40.9091,  addrinfo 172.27.136.0
[INFO][0][cell id 18, geo id 19, leo id 36, startposi        18, 8.18182,  addrinfo 172.27.144.0

```

Fig. 7. Output record of location area

Due to the need of avoiding address ambiguity, the link-based centralized address allocation method must ensure that the address is in a different subnet segment when the link of interfaces is different. Therefore, it is impossible to aggregate addresses based on the hierarchical relationship of the network. When the satellite nodes in the network are kept unchanged as shown in Table 1 and the number of access terminals is increased, the required IP address resources are shown as the figure below compared with the method based on geographic division. Since the address allocation method based on geographic partition can effectively use the location area for addressing without address ambiguity, the occupied address space can be smaller. The difference is more obvious when there are more terminals (Fig. 8).

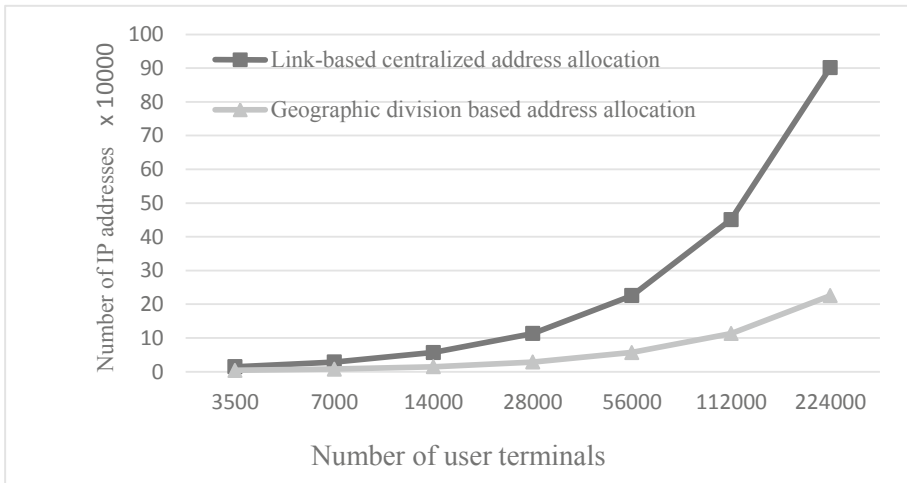


Fig. 8. Comparison of IP address resources occupied by different methods

The overall result of address allocation shows that the designed address allocation method can meet the needs of the space-based network operation, and can ensure that the address resources are saved under the premise of no conflicts, which provides an effective reference for the development of the space-based network.

4.2 Data Transmission and Address Management Simulation

When the address allocation in the network is completed, the nodes in the simulation scenario start to run. LEO nodes broadcast to neighboring satellites according to their own routing tables, and update their own routing tables according to the received information of other nodes. In the case of one broadcast interval, the routing tables of all LEO nodes reach convergence after five broadcast cycles. All interfaces are recorded in the routing table, and the data is shown in the following Fig. 9:

| #LEO id: 1 | | | | |
|--------------|-----------------|--------------|--------------|----------|
| DstAddr | SubnetMask | NextHop | OutputIntrf | Distance |
| 0.0.0.0 | 0.0.0.0 | 172.26.128.1 | 172.26.128.3 | 32 |
| 172.22.0.141 | 255.255.255.252 | 172.22.0.141 | 172.22.0.142 | 1 |
| 172.22.0.145 | 255.255.255.252 | 172.22.0.141 | 172.22.0.142 | 1 |
| 172.22.0.146 | 255.255.255.252 | 172.22.0.154 | 172.22.0.153 | 2 |
| 172.22.0.150 | 255.255.255.252 | 172.22.0.150 | 172.22.0.149 | 1 |
| 172.22.0.154 | 255.255.255.252 | 172.22.0.154 | 172.22.0.153 | 1 |
| 172.22.0.157 | 255.255.255.252 | 172.22.0.150 | 172.22.0.149 | 1 |
| 172.22.0.158 | 255.255.255.252 | 172.22.0.150 | 172.22.0.149 | 2 |
| 172.22.0.161 | 255.255.255.252 | 172.22.0.150 | 172.22.0.149 | 1 |
| 172.22.0.162 | 255.255.255.252 | 172.22.0.154 | 172.22.0.153 | 2 |
| 172.22.0.165 | 255.255.255.252 | 172.22.0.150 | 172.22.0.149 | 2 |
| 172.22.0.166 | 255.255.255.252 | 172.22.0.150 | 172.22.0.149 | 3 |

Fig. 9. Partial routing table of LEO node

After the scene starts to operate, the ground terminal nodes also start to join the network. After calculating the location area to which they belong and establishing a link with the corresponding access layer node. Then they start to communicate with the peer at a random rate after obtaining the IP address, and record the transmission process of some node groups in the log. The log also records a handover of the terminal between the service and proxy satellite of location area.

As shown in the figure below, in the operation of the space-based network, with the assistance of the proxy and the service role, the handover of the satellite to the ground area no longer means that the connection with the terminal in the area will be immediately interrupted, and the terminal can choose proper time to switch according to its own data transmission situation. The application layer session of the ground terminal shields the satellite service and proxy partition changes, so that routing and addressing can still be normally achieved (Fig. 10).

```

[300000000][l]st GrUser Info: IPaddr: 172.28.176.3, 255.255.248.0; GrZone: 50; CurSAT & CurItf: 68, 5; SrvSAT & ProxySAT: 68, -1
[120000000][l]st GrUser Info: IPaddr: 172.28.176.3, 255.255.248.0; GrZone: 50; CurSAT & CurItf: 68, 5; SrvSAT & ProxySAT: 68, -1
[210000000][l]st GrUser Info: IPaddr: 172.28.176.3, 255.255.248.0; GrZone: 50; CurSAT & CurItf: 68, 5; SrvSAT & ProxySAT: 68, -1
[300000000][l]st GrUser Info: IPaddr: 172.28.176.3, 255.255.248.0; GrZone: 50; CurSAT & CurItf: 67, 5; SrvSAT & ProxySAT: 68, 67
[390000000][l]st GrUser Info: IPaddr: 172.28.176.3, 255.255.248.0; GrZone: 50; CurSAT & CurItf: 67, 5; SrvSAT & ProxySAT: 68, 67
[480000000][l]st GrUser Info: IPaddr: 172.28.176.3, 255.255.248.0; GrZone: 50; CurSAT & CurItf: 67, 5; SrvSAT & ProxySAT: 68, 67
[570000000][l]st GrUser Info: IPaddr: 172.28.176.3, 255.255.248.0; GrZone: 50; CurSAT & CurItf: 67, 5; SrvSAT & ProxySAT: 68, 67
[660000000][l]st GrUser Info: IPaddr: 172.28.176.3, 255.255.248.0; GrZone: 50; CurSAT & CurItf: 67, 5; SrvSAT & ProxySAT: 68, 67
[750000000][l]st GrUser Info: IPaddr: 172.28.176.3, 255.255.248.0; GrZone: 50; CurSAT & CurItf: 67, 5; SrvSAT & ProxySAT: 67, 68
[840000000][l]st GrUser Info: IPaddr: 172.28.176.3, 255.255.248.0; GrZone: 50; CurSAT & CurItf: 67, 5; SrvSAT & ProxySAT: 67, 68
[930000000][l]st GrUser Info: IPaddr: 172.28.176.3, 255.255.248.0; GrZone: 50; CurSAT & CurItf: 67, 5; SrvSAT & ProxySAT: 67, 68
[1020000000][l]st GrUser Info: IPaddr: 172.28.176.3, 255.255.248.0; GrZone: 50; CurSAT & CurItf: 66, 6; SrvSAT & ProxySAT: 67, 66
[1110000000][l]st GrUser Info: IPaddr: 172.28.176.3, 255.255.248.0; GrZone: 50; CurSAT & CurItf: 66, 6; SrvSAT & ProxySAT: 67, 66
[1200000000][l]st GrUser Info: IPaddr: 172.28.176.3, 255.255.248.0; GrZone: 50; CurSAT & CurItf: 66, 6; SrvSAT & ProxySAT: 67, 66
[1290000000][l]st GrUser Info: IPaddr: 172.28.176.3, 255.255.248.0; GrZone: 50; CurSAT & CurItf: 66, 6; SrvSAT & ProxySAT: 66, 67
[1380000000][l]st GrUser Info: IPaddr: 172.28.176.3, 255.255.248.0; GrZone: 50; CurSAT & CurItf: 66, 6; SrvSAT & ProxySAT: 66, 67
[1470000000][l]st GrUser Info: IPaddr: 172.28.176.3, 255.255.248.0; GrZone: 50; CurSAT & CurItf: 66, 6; SrvSAT & ProxySAT: 66, 67
[1560000000][l]st GrUser Info: IPaddr: 172.28.176.3, 255.255.248.0; GrZone: 50; CurSAT & CurItf: 65, 5; SrvSAT & ProxySAT: 66, 65
[1650000000][l]st GrUser Info: IPaddr: 172.28.176.3, 255.255.248.0; GrZone: 50; CurSAT & CurItf: 65, 5; SrvSAT & ProxySAT: 66, 65

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Fig. 10. Handover between ground terminal and satellite

4.3 Visual Demonstrate

In order to better demonstrate and analyze the operation of the space-based network and the address allocation management method, a three-dimensional demonstration of the scene operation process was developed. During initialization, the visualization platform receives node type and quantity information. When the simulation scene time is greater than 0, the scene platform updates the topology of the space-based network in real time and sends it to the visualization platform. It also updates the location area information and the address information of each node interface.

As shown in the figure below, according to the different orbit radii, the positions of GEO nodes and LEO nodes can be seen, and the links between satellites with different orbit altitudes are hidden to better reflect the operating status of the access layer nodes. When the simulation scenario is running, you can click on the node to view the IP address and routing table information of each interface to observe the address allocation and network operation (Fig. 11).

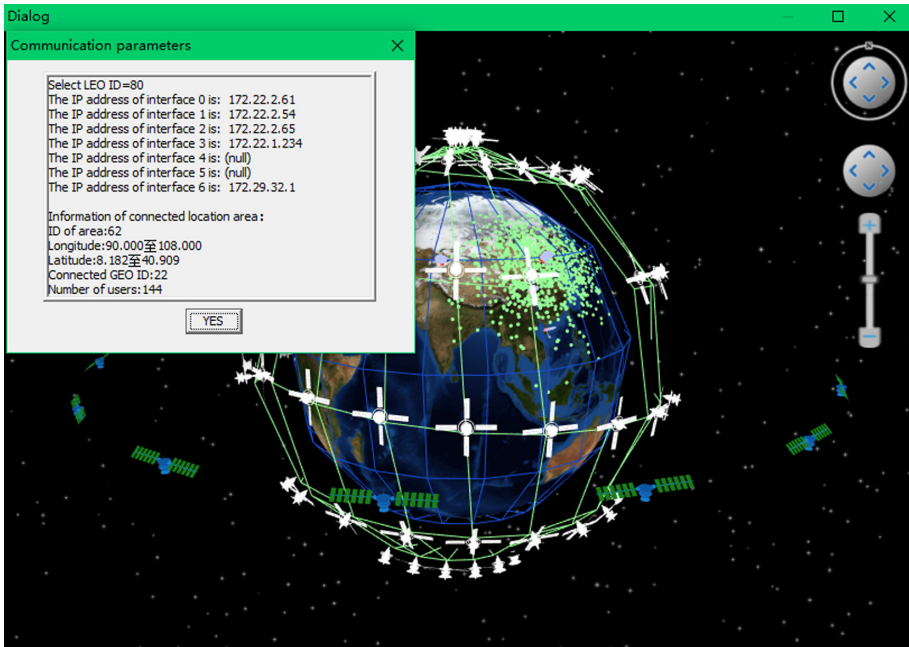


Fig. 11. Visualization of the operation and address allocation of the space-based network

5 Conclusion

In this paper, under the background of continuous development of space-based network technology research, the main methods of address allocation management in the network are studied. We first examined the problems of interface address allocation and access terminal management faced by space-based networks in actual operation. Then, according to the characteristics of the space-based network, a method for address allocation to each node interface in the space-based network is proposed. This method greatly reduces the number of addresses required in the network. Then we propose an address management scheme when the network is running, so that users can maintain a smooth transition at the network layer during satellite switching. Finally, the address allocation and management scheme was developed and verified in the simulation scenario, and the feasibility of network operation was demonstrated through visualization.

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