Research on Optical-Electrical Path Mapping Strategy of Space Hybrid Switches

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Abstract. To solve the problem of heterogeneous path selection, which is caused by the classification, collection, and exchange of multi-layer services in the space information network. An optical-electrical path mapping strategy is proposed. The strategy establishes a normalized identification for the forwarding information and status information, these information are required for each layer switch. The strategy establishes an internal path mapping table. The algorithm enables the services of various granularities in the space to flexibly select internal paths, It can realize the deep integration of multi-layer switching.

Keywords: Hybrid switches · Optical-electrical path · Path mapping table · Space information network

1 Introduce

The structure of the space information network is complex, the information is multi-dimensional, the information representation is diverse, the amount of information is huge, the information relationship is complex, the timeliness, accuracy and reliability of information processing are high. Multi-granularity heterogeneous data exchange at the physical layer (optical layer)/link layer/network layer is required.

In traditional hybrid switching, whether it is in a terrestrial network or in a space network, the optical layer and the electrical layer use different mapping tables to select the internal path [1–3]. The optical switch forwards wavelengths or time slots at the physical layer according to the configuration table. The electrical packet forwards according to the forwarding table and routing table, it adopts two-layer and three-layer switching technology. It is difficult for the tables of different layers to interact, it is not conducive to centralized control of the resources within the switch.

This paper proposes an optical-electrical path mapping strategy in space hybrid switching, this strategy unifies the internal path information and switching matrix state information in the internal path mapping table of the second layer, these information is required by the optical layer and the electrical layer. Various granular switching services can quickly obtains the information of all available paths with this mapping table. The services can flexibly choose different paths, such as optical paths or electrical paths. This strategy not only meets the fast forwarding requirements of each user's data, but also realizes the deep integration of multi-layer switching.

B. Li et al. (Eds.): IoTaaS 2020, LNICST 346, pp. 363–370, 2021.
https://doi.org/10.1007/978-3-030-67514-1_29

2 Space Hybrid Switch Technology

2.1 Space Information Network

There are three main types of links and services that space information network nodes access: one is backbone service links, including GEO-GEO links, GEO-ground gateway station links, etc., these are relatively static links. One is the space nodes and User links, including links between GEO and LEO, aerospace vehicles, nearby space vehicles and other users. The other is the links which is used in some specific situations, such as distributed intra-constellation communications, satellite formation flying, etc. It can be said that space information has the characteristics of diversified services and protocols, and large differences in service quality requirements [4] (Fig. 1).

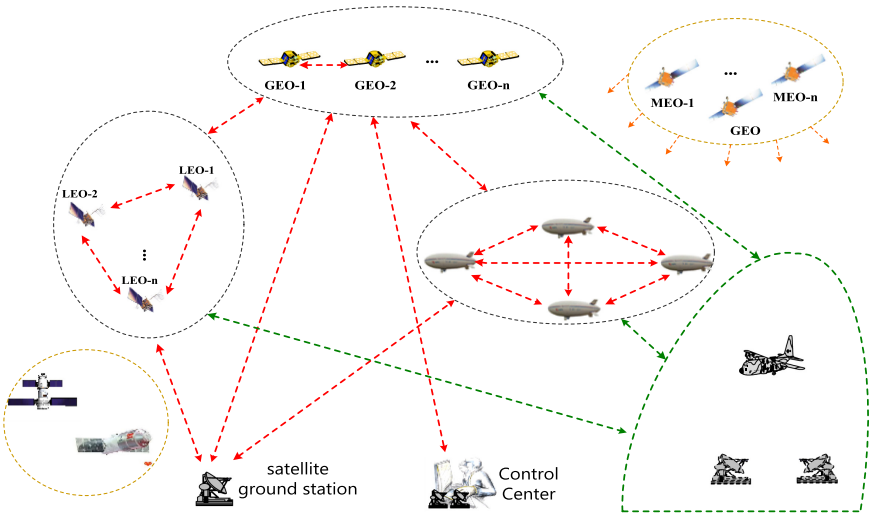

Fig. 1. Conception of the space information network.

The first type of link information only needs to be forwarded transparently in the space node, the second type of link information requires service aggregation and multi-granularity distribution in the space node, and the third type of link information needs to be forwarded quickly, but also needs to be aggregated, distribution. Because of this, there are two forwarding requirements for space information: one is that it only needs to be forwarded transparently, and the other is that it needs to be distributed with multiple granularities. When small-granularity port services are forwarded to large-granularity port services, the unified control is required.

2.2 Optical-Electrical Hybrid Switching

Electrical packet switching technology and optical circuit switching technology are quite different in services granularity, but the integration of optical-electrical switching

technology can be achieved in the node, through sophisticated intelligent service management technology (including service aggregation/grooming, optical layer bypass technology, etc.), optical-electrical hybrid switching has multi-granularity switching capabilities, and there are physical layer, two-layer, and three-layer switching at the same time [5, 6]. They implement information forwarding according to physical or logical internal paths (Fig. 2).

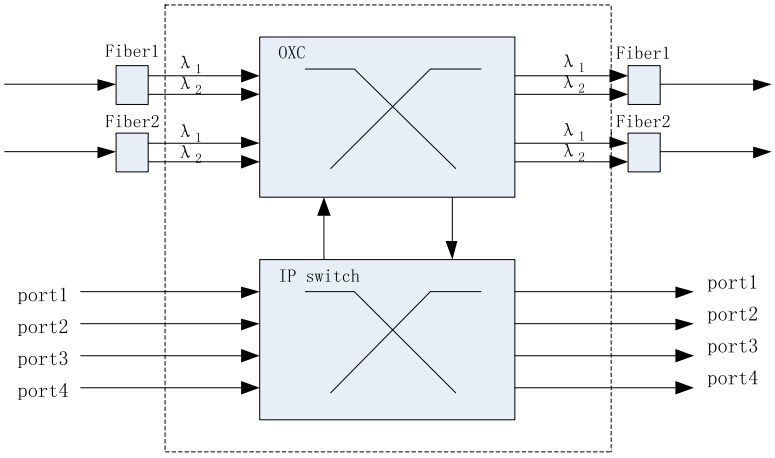

Fig. 2. Optical-electrical hybrid switching unit

Therefore, in order to unify scheduling, aggregation, and distribution of space information, the space hybrid switching needs to establish a unified forwarding basis for all information, thereby shielding the differences between different resources [7, 8].

3 Optical-Electrical Path Mapping Strategy

Whether it is optical or packet switching, this research abstracts the management/control of data flow through the method of normalizing labels. The normalized label here contains multi-dimensional information of data [9, 10]. For example, optical switching uses available time slots and wavelengths to characterize optical data exchange information, while packet switching uses destination IP addresses to characterize packet data exchange information (Fig. 3).

3.1 Internal Path Mark Mapping

(1) Port mapping

In the optical-electrical hybrid switching node, for the optical switching matrix: if it is wavelength and band switching, assume that n is the number of wavelengths of the optical switching matrix; if it is optical switching matrix switching, assume that n is the

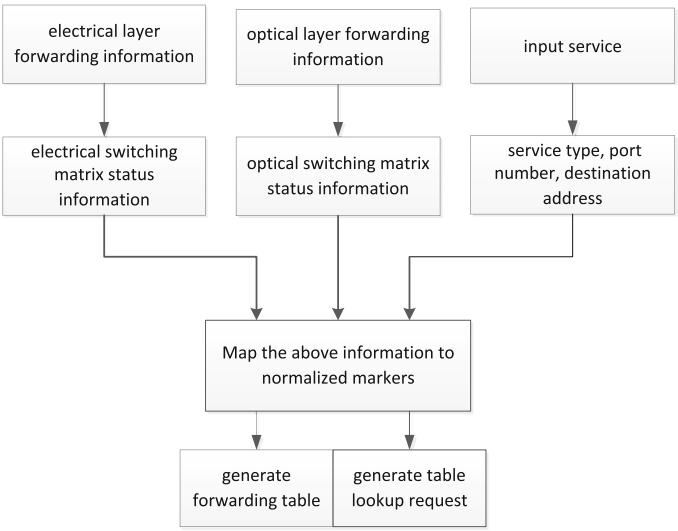

Fig. 3. Overall scheme of path mapping

number of optical switching matrix number of input/output ports. For electrical switching: suppose m is the number of input and output ports of the electrical switching matrix. The following mapping relationships can be established (Fig. 4).

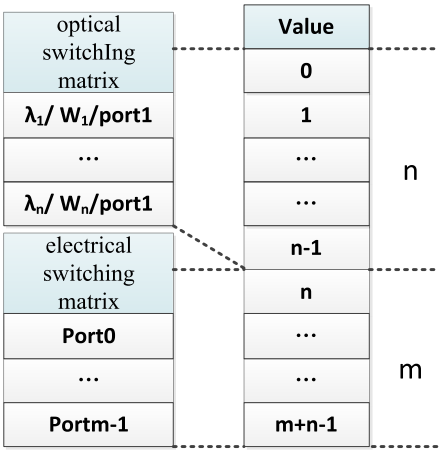

Fig. 4. Port mapping method

As shown in the figure above, the wavelength/band/port of the optical switching matrix and the port of the electrical switching matrix are mapped to a set of integers, with a value range of $0 \sim m+n-1$, the mapping table is used for fast forwarding, the

input and output port number can be mapped to a binary number, and its bit width is m +n, and each wavelength and port are identified by the bit of the binary number.

(2) Switching matrix state mapping

Collect the status information of the optical/electric switching matrix in real time, including the occupancy and congestion of internal paths. If the wavelength/band/port is already occupied, it is marked as "11", and if it is idle, it is represented as "00". If the wavelength/band/port is not occupied, and estimated that it cannot transmit a large number of reports in a short time. It is marked as quasi-idle "01", if the in/out port of this electrical switching matrix is congested, it is marked as "11", otherwise it is marked as "00". The obtained state information is integrated and mapped into two binary numbers with a bit width of 2 (m+n). The above-mentioned identification can be used to generate an internal path mapping table (Fig. 5).

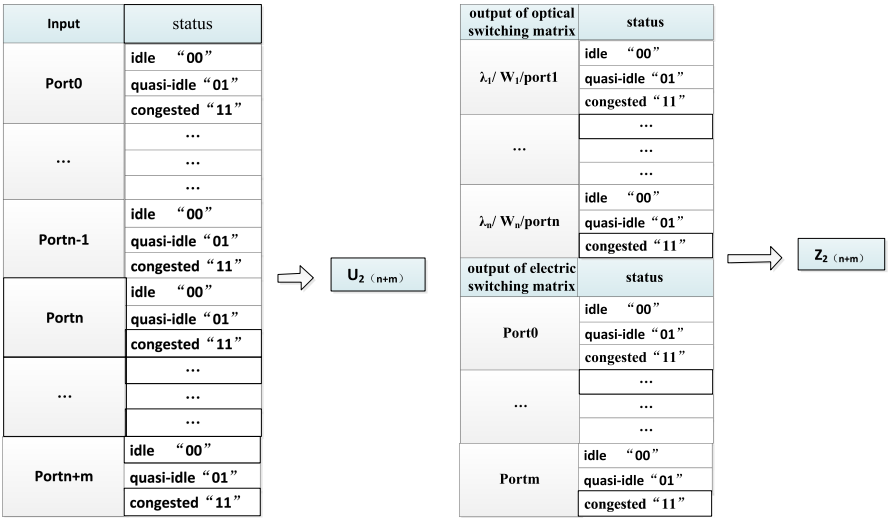

Fig. 5. The specific method of switching matrix state mapping

(3) The internal path mapping of the switch

- Establish the mapping relationship between the destination address and the input/output ports of the switch;
- When a destination address corresponds to a unique output port, set the bit position corresponding to this port to "1", and set the rest to "0". When a destination address corresponds to k output ports, set the bits corresponding to these k ports Position "1", and set the rest to "0";
- Establish a one-to-one correspondence between each input port of the switch and the destination address. If the input port is an optical port, the table entries is generated, and it includes optical input port → optical output port → destination address, optical input port → electrical output port → destination address, optical

input port → electrical input port → electrical output port → All possible paths to the destination address; similarly, if the input port is an electrical port, the table entries is generated, and it includes electrical input port → electrical output port → destination address, electrical input port → optical output port-destination address, electrical input port → optical input port → optical output port → destination address.

- Establish the mapping of multi-dimensional information lookup table request;
- The service type is divided into two parts: multi-dimensional information identification and service type identification. The multi-dimensional information identifier is used to distinguish whether the input data is optical data or packet data, and the service type identifier is used to distinguish the priority of the data packet. Combining the table lookup result of the input data message with the service type, the appropriate forwarding output port and switching granularity can be selected according to different needs;
- Use the input port number and destination address as the read address for quick table lookup. Addra = input port number*the number of destination address. The destination address can be the next hop IP address, MAC address, or a custom label, as long as it can uniquely identify all switches and users in the same network.

(4) Optical\electrical additional information mapping

Establish additional information items of optical/electricity, it is reserved for different needs. For example: for the optical input port, if the switching matrix is a switch matrix, the optical identifier will provide the optical switch path information from the input port to the output port in the switching matrix, it includes all optical switches in use in the occupied path.

3.2 The Table of Internal Path Mapping

Valid bit: Identifies whether the forwarded information is valid;

Optical identification: used to identify the resource occupancy of each port in the optical switching matrix;

Input port number: Input the port number of the optical data packet/input the port number of the packet data packet;

Output port number: the port number of the output port to which the input optical data packet is to be switched, and the port number of the output port to which the input packet data packet is to be switched;

Port status information: used to identify the resource occupation of each port of the switch;

Multicast identifier: indicates the packet data;

Next hop address: Enter the address of the next hop router to be exchanged for data packets (Fig. 6).

Valid bit	Optical identification	Input port number	Output port number	Port status information	Multicast identifier	additional information	Next hop address
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…

Fig. 6. The format of Internal path mapping table

3.3 Create a Table Lookup Request

The services type is divided into two parts: optical/electrical identification and message type identification. Optical/electrical identification is used to distinguish whether the input service is optical data or packet data; the service type identification is used to distinguish the priority of the message, and the result of the table lookup of the input service and the service type can be selected according to different needs. Appropriate forwarding and output ports and switching granularity (Fig. 7).

services type	Input port number	Next hop address

Fig. 7. The format of table lookup request

3.4 Query Steps of the Path Mapping Table

i. When the input message needs search the internal path, firstly, confirm whether the input port is occupied or not, by according to the state information of the switch matrix generated in the previous article. If it is not occupied, perform 2;
ii. According to the destination address in the message of table lookup request, reads the mapping table entry in the memory, and establishes a fast internal switching path according to the output port number and matrix status information of the optical-electrical switch matrix. If the output port queried is Occupied, execute 3
iii. The mapping table are searched in the same clock cycle to find the corresponding entry, for all port numbers except the current message input port number, and then the table entries corresponding to the message destination address are read. According to the information such as the optical-electrical identification and effective bit of the entry, the appropriate entry is selected to establish the optimal internal path.
iv. When the switching matrix performs a message exchange and the status information changes, the internal path mapping table will update in time.

4 Conclusion

Firstly, this paper analyzes the needs of the forwarding and processing for space information network, it gives the principle of space hybrid switching, and it proposes an optical-electrical path mapping strategy for space hybrid switching, This strategy completes some key technical designs, such as port mapping, switching matrix state mapping, and internal path mapping of switches. Optical-electrical hybrid switching is based on this internal path mapping method, it can realize fast forwarding from electricity to light and light to electricity, and can also realize resource integration inside the switch, thus it can concentrates the advantages of the electrical and optical layers, and improves link utilization. This strategy provides technical support for the integration of space optical network and power grid.

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