



Design and Realization of Onboard Router Based on IPv6 and SPP with Software

Zheng Qi^(✉), Xiongwen He, Panpan Zhan, Cuitao Zhang, Ming Gu,
and Dong Yan

Beijing Institute of Spacecraft System Engineering,
Beijing 100094, People's Republic of China
qzqz365@126.com

Abstract. For the purpose of Spacecraft Networking, considering the factor of the deployment of SPP within SOIS protocol system and the deployment of IPv6 in ground network with its development in the future, we present a set of scheme about design and realization, with software, of onboard router based on IPv6 and SPP. The design and realization of onboard router provides a new idea on constructing the Integrated Space-Ground Network, establishing the foundation of Spacecraft Networking in the future.

Keywords: IPv6 · SPP · SOIS · Route · Spacecraft Networking

1 Introduction

Along with the proposal of constructing Integrated Space-Ground Network, some domestic enterprises and universities have already researched in relative fields of Integrated Space-Ground Network and have obtained pretty good results [1]. Among the fields, spacecraft networking is considered as a very important theme, worthy of being deeply researched.

Until now, onboard equipment of traditional spacecraft has deployed SOIS protocol system of CCSDS, and treats the SPP of transport layer as the routing protocol within spacecraft [2]. Besides, for the purpose of taking good advantage of networking and routing technology, unifying message format and protocol between equipment, improving equipment's versatility and flexibility, decreasing development cost, IPv6 protocol [3] has been deployed in a part of modern spacecraft for networking between spacecraft.

Although IPv6 and SPP can resolve the problem of data routing, but SPP is originally developed to resolve the routing problem intra-spacecraft, not inter-spacecraft. Considering the deployment of SPP within SOIS protocol system, it is unrealistic or difficult to deploy IPv6 protocol on all onboard equipment in the near future at least [2]. So, how to use IPv6 and SPP to realize spacecraft networking, more specifically, end-to-end communication between equipment of different spacecraft, is the key point of this paper.

In this paper, we briefly analyze the feature of IPv6 and SPP and propose a reasonable scheme about design and realization of onboard router with software based

on IPv6 and SPP. Besides, we present a typical topology or scenario to verify the rationality of the scheme, establishing the foundation of Spacecraft Networking in the future.

2 Protocol Analysis

2.1 IPv6

IPv6, version 6 of Internet Protocol, is used to expand IPv4 for reasons of address space, simplification, etc. Due to reasonable fields of IPv6 packet format, IPv6 has been proved reasonable and reliable in Terrestrial Internet and can satisfy the demand for constructing global network and local network among IPv6 equipments, even IPv4 equipments with tunnel. Besides, because of kinds of address types, described in following chapter, it is possible and realistic to use IPv6 in spacecraft to construct network in space.

However, IPv6 has not been deployed in traditional spacecraft owing to user's requirement and even though it is used in some modern spacecraft, it also can't be compatible with SPP of SOIS till now, even taking the place of SPP in spacecrafts.

So, it's still difficult to deploy IPv6 on all onboard equipments to resolve the problem of constructing network and routing within spacecraft, even with other spacecrafts [3].

2.2 SPP

The SPP in SOIS communication protocol system, has been proved feasible and reliable to resolve the problem of constructing network and routing within spacecraft, using Destination APID, etc. However, the APID and other identifier used in SOIS only has local meaning and don't have global meaning, just like local IP address.

Besides, considering that the era and background of this protocol, we didn't expect to construct network among spacecrafts, just between earth and spacecraft. But, this should have been taken into account.

So, for SPP, it is not suitable for construct network among spacecrafts [4, 5].

3 Routing Scheme

For the above-mentioned contents, if we want to realize the routing for the onboard equipment of different spacecraft, IPv6 and SPP need to be changed and merged.

3.1 IPv6

As the following figure shows, the customization of IPv6 protocol is IPv6 address format [6] (Fig. 1).

The meaning of every field of this format is shown below (Table 1).



Fig. 1. Customization on IPv6 address format

Table 1. Field meaning

| Name | Meaning |
|----------------------|---|
| Address Type | Type of IPv6 address (Unicast, Multicast, etc.) |
| Network Element ID | Spacecraft ID or ground equipment ID |
| Subnet ID | The subnet ID of onboard gateway interface |
| Interface Identifier | Same as the Interface Identifier of normal IPv6 address |

It is easy to identify every IPv6 equipment in every spacecraft with the format and it is compatible for this format with normal IPv6 address format.

3.2 SPP

The customization of SPP is mainly focused on its payload, Application Management Layer (AML) Service. As shown below, it’s useful to carry two fields ahead of the valid data field (Fig. 2).

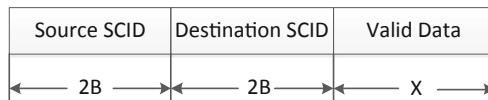


Fig. 2. AML service format

The meaning of every field of the format is shown below (Table 2).

Table 2. Field meaning

| Name | Meaning |
|------------------|--|
| Source SCID | Source spacecraft ID of current message |
| Destination SCID | Destination spacecraft ID of current message |
| Valid Data | Real application data |

Besides the payload, when receives space packet, SPP firstly judges the destination of current message whether is current spacecraft by “Destination SCID” field, then transfers SPP to IPv6. IPv6 can realize the communication between onboard equipment of different spacecraft.

3.3 Protocol Information Map

The conversion of transferring SPP to IPv6 is established on the mapping information as shown below (Table 3).

Table 3. Protocol information map

| Network Element ID | Address Type | Subnet ID | APID |
|--------------------|--------------|-----------|-------|
| 0xAA | 0xFD000000 | 1 | 0x4AD |
| | | | 0x44A |
| | | | 0x9BD |
| | | ... | ... |
| | | | 0xB21 |

The map, calling PIM below, can be initialized by ground control unit and later updated. Besides, after the built of spacecraft, every field associated with the spacecraft in the map can be fixed and the “Network Element ID” field has global meaning for networking.

The routing scheme or packet handling process is based on the three points mentioned above and is described in the following chapter for the reason of content arrangement of this paper.

4 Gateway Equipment

The two routing protocols’ transformation needs to be done by a kind of gateway unit. In this paper, we designed an onboard router to do it. The software of the router, calling CPU below, needs to support the two protocols. If the message needs to be transmitted to other spacecraft or other link subnet within spacecraft, SPP will be encapsulated in IPv6 packet as payload which is same as the tunnel scheme between IPv4 and IPv6 [7].

The protocol stack of the onboard router is shown below (Fig. 3).

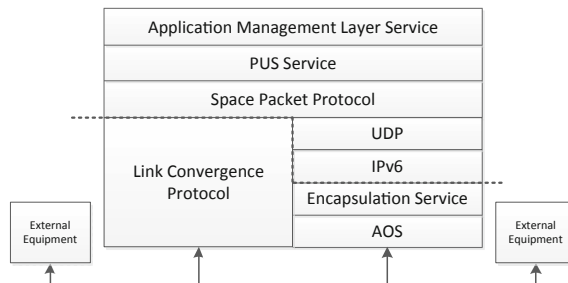


Fig. 3. Protocol stack diagram within router

In this paper, router’s job is mainly focused on the part of the dash line above. We can see that the SPP can be the routing protocol within SOIS and also be the payload of IPv6 packet. Because the router executes the routing scheme in the chapter above, the flow chart about processing IPv6 packet and space packet in router is shown below (Fig. 4).

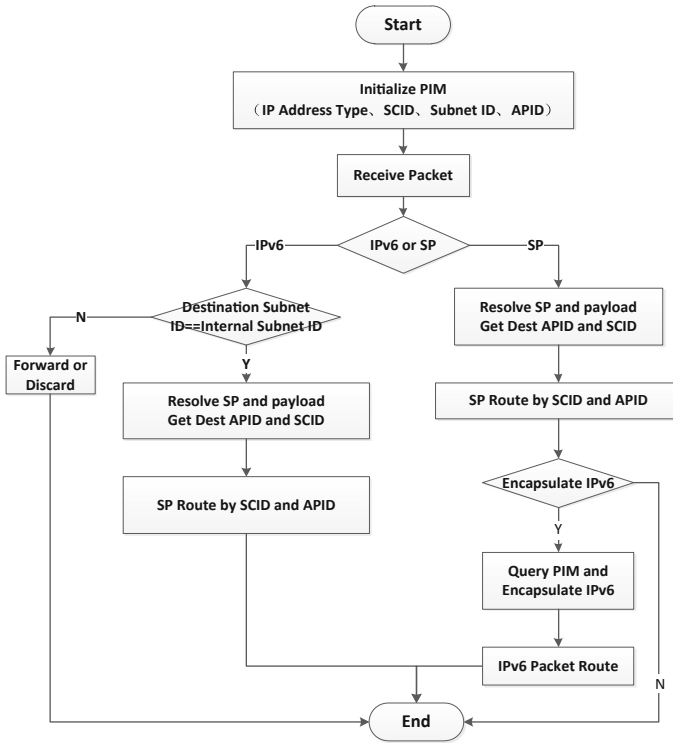


Fig. 4. Flow chart of packet processing

Step 1. Initialize PIM

Router firstly initializes the PIM according to the ground control unit’s command, convenient for the transformation of space packet to IPv6 packet.

Step 2. Routing from IPv6 to SPP

- (1) After receiving IPv6 packet, the router judges the destination port according to the address prefix length and destination IPv6 address.
- (2) For the incoming IPv6 packet, CPU resolves it and obtains the payload, space packet.
- (3) After obtaining the destination APID, CPU delivers the space packet to the SPP of transfer layer to route to other link subnet.

Step 3. Routing from SPP to IPv6

- (1) After receiving space packet, the router extracts the destination APID from space packet and destination SCID from AML Service.
- (2) (According to the SCID, the router firstly determines whether to route using SPP. If SCID doesn't equal to current spacecraft's SCID, router queries the PIM, encapsulates IPv6 packet and routes packet to outside by queries routing table; Otherwise, goes to 3).
- (3) Routing space packet. If the destination link type is Ethernet, router also transfers space packet to IPv6 packet, transmit the packet to destination equipment by IP route. Otherwise, router encapsulates space packet into Packet Service and then to destination link subnet base on space packet routing [2].

5 Systematic Verification

The scheme, presented in this paper, can be verified in typical topology and has been realized in physical onboard router. The typical topology is shown below (Fig. 5).

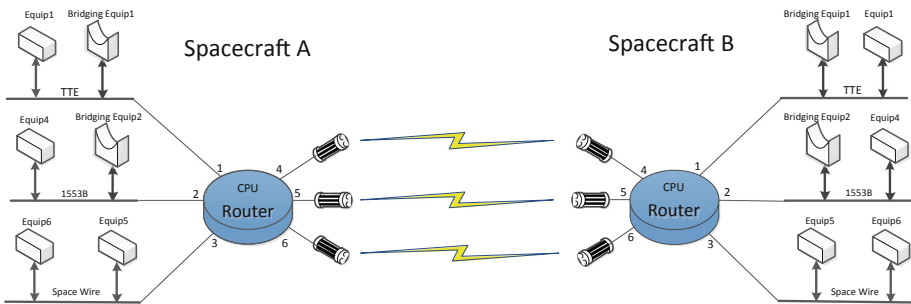


Fig. 5. Typical network topology diagram

As shown above, onboard router is equipped as spacecraft's gateway and connects three different links via interface 1–3 inside of spacecraft. Equipment 1 and bridging equipment 1, equipped on TTE, belong to subnet 1. Equipment 4 and bridging equipment 2, equipped on 1553B bus, belong to subnet 2. Equipment 5 and 6, equipped on Space Wire, belong to subnet 3. Meanwhile, router connects three laser terminals. Every interface belongs to a subnet. Besides, the router of spacecraft A connects to the router of spacecraft B with inter-spacecraft link. The connection between routers will be changed along with spacecraft's movement.

The typical topology above can support two end-to-end route scenarios shown below.

- Intra-Spacecraft

According to this paper’s focus, we only describe the end-to-end route between equipment A linked by 1553B and equipment B linked by Ethernet. The system protocol configuration is shown below (Fig. 6).

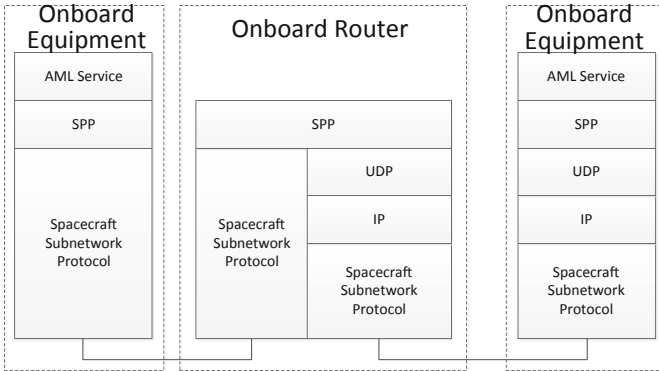


Fig. 6. Intra-spacecraft end-to-end route system protocol configuration

As shown above, Ethernet link can also be fitted into scope of Subnetwork Layer of SOIS. Equipment A encapsulates AML Service via PUS Service, space packet, Packet Service and routes it to the router by space packet routing. Router extracts destination APID from space packet and destination SCID from AML Service and finally routes the space packet to destination link, encapsulating space packet via UDP, IPv6, MAC [7].

- Inter-Spacecraft

The end-to-end route system protocol configuration between equipment of different spacecraft is shown below (Fig. 7).

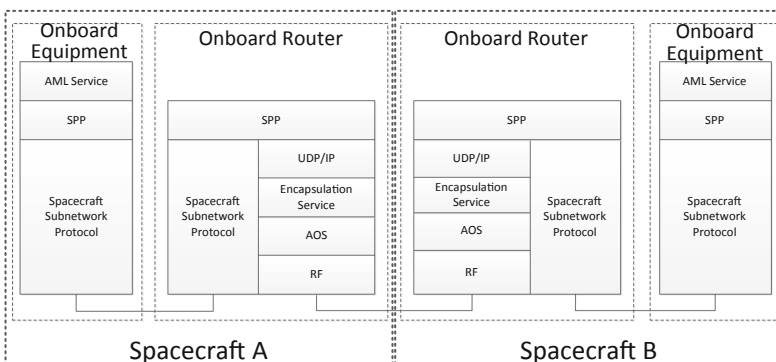


Fig. 7. Inter-spacecraft end-to-end route system protocol configuration (direct connection)

As shown above, equipment within spacecraft A encapsulates AML Service via PUS Service, space packet, Packet Service and routes it to the router by space packet routing. Router extracts destination APID from space packet and destination SCID from AML Service and finally routes the space packet to spacecraft B via UDP, IPv6, ES (Encapsulation Service), AOS and RF. The router of spacecraft B routes IPv6 packet into spacecraft B by querying IP routing table, extracts space packet and routes space packet to destination link by space packet routing. Finally, equipment within spacecraft B receives packet and extracts message from Packet Service, space packet, PUS Service, realizing the end-to-end communication [8–10].

Besides, if the end-to-end route between source spacecraft and destination spacecraft needs to be relayed by relay spacecraft, the system protocol can be configured as the following figure shows (Fig. 8).

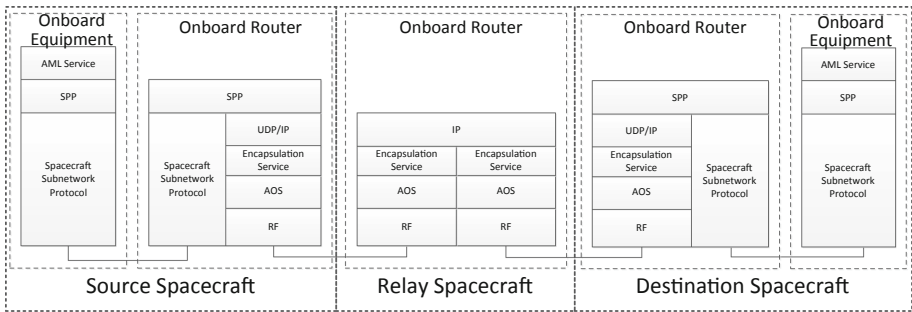


Fig. 8. System protocol configuration of relay system

Under the current circumstances, the relay spacecraft only needs to forward IPv6 packet by querying routing table, no additional operation like analyzing space packet.

6 Conclusion

In this paper, we firstly analyzed the feature of IPv6 and SPP and then introduced a reasonable scheme about design and realization of onboard router with software. By means of combining this two routing protocols, the scheme both meet the requirement of data routing intra-spacecraft and inter-spacecraft. Although the scheme has been proved reasonable and feasible, it's necessary to deploy the scheme in much more systems. The proposal of the scheme establishes the foundation of Spacecraft Networking in the future.

References

1. Manqing, W., Wei, W., Zhou, B., et al.: Some thoughts of integrated space-ground network architecture. *Satell. Netw.* **10**(3), 30–36 (2016)
2. Zhao, H., He, X., Liu, C.: *Space Data System*, 1st edn. Beijing University of Technology Press, Beijing (2018)
3. Hinden, R., Deering, S.: RFC 2460, Internet Protocol, Version 6 (IPv6) Specification, Network Working Group (1998)
4. CCSDS: CCSDS 850.0-G-2, *Spacecraft Onboard Interface Services*, Washington, D.C., USA, CCSDS (2013)
5. CCSDS: CCSDS 133.0-B-1, *Space Packet Protocol*, Washington, D.C., USA, CCSDS Secretariat (2003)
6. Hinden, R., Deering, S.: RFC 3513, IP Version 6 Addressing Architecture, Network Working Group, 4 (2003)
7. Andrew, S.: *Tanenbaum: Computer Networks*, 4th edn. TsingHua University Press, Beijing (2004)
8. CCSDS: CCSDS 133.1-B-2, *Encapsulation Service*, Washington, D.C., USA, CCSDS Secretariat (2009)
9. CCSDS: CCSDS 732.0-B-3, *AOS Space Data Link Protocol*. Washington, D.C., USA, CCSDS Secretariat (2015)
10. CCSDS: CCSDS 851.0-M-1, *Spacecraft Onboard Interface Services-Subnetwork Packet Service*, Washington, D.C., USA, CCSDS Secretariat (2009)