2015 4th International Conference on Informatics, Environment, Energy and Applications
Volume 82 of IPCBEE (2015)
DOI: 10.7763/IPCBEE. 2015.V82.17

Analysis of IP Packet Encapsulation Efficiency of Satellite Links

ZHANG Zhen[11], MA Zheng-xin[1], WANG Hang[2]

[1] Department of Electronic Engineering, Tsinghua University, Beijing 100084, China;
[2] Hebei SHENZHOU SATCOM Co., LTD., Shijiazhuang 050200, China

Abstract. With the rapid development of Internet technologies, IP data transmission via satellite networks has become a hot topic in the field of satellite communications. IP packet encapsulation protocol is a key technology. This paper studies three main IP packet encapsulation protocol formats, that is, MPE, ULE and GSE. A comparison of performances is made between the three formats. Finally, an improved GSE-Improved encapsulation format is put forward in regards of IP data transmission via the remote station return link of a star-shape satellite network. As compared with GSE, the encapsulation efficiency is improved, and the encapsulation process is simplified.

Keywords: MPE, ULE, GSE, IP, GSE-Improved, encapsulation efficiency.

1. Introduction

Satellite communication has many advantages, such as wide coverage and long communication distance. It plays an important role of in the fields of radio and television, remote sensing, private network communication and emergency communication. In recent years, with the rapid development of Internet technologies based on IP data transmission, IP data transmission via satellite links becomes an important development trend of satellite communication. The satellite communication link operates in a complex environment. The external interference is quite serious. Therefore, IP packets should not be transmitted directly, it is necessary to encapsulate the IP data packet of variable length into a data transmission format suitable for satellite communication links. At present, there are three main IP data encapsulation methods, namely, Multi-Protocol Encapsulation (MPE), Unidirectional Lightweight Encapsulation (ULE) and General Stream Encapsulation (GSE). MPE was first introduced by the European Telecommunications Standards Institute (ETSI) in the Standards of Digital Video Broadcasting-Satellite (DVB-S). MPE has a lower IP data encapsulation efficiency and a more complicated structure, but it is still the main encapsulation technology used in the current applications. ULE encapsulation protocol made some improvements, but the performance improvement is quite limited. GSE protocol greatly improves IP data encapsulation efficiency and the encapsulation structure is also greatly simplified.

Based on an analysis of the three main encapsulation protocols, this paper puts forward an improved GSE-Improved encapsulation method for IP data transmission via the remote station return link of a star-shape satellite network. Encapsulation efficiency is further improved.

2. Encapsulation of IP Data Packets

MPE encapsulation is a data encapsulation technology introduced by ETSI in the DVB-S Technical Specifications. MPE is a widely used mature technology, but it has lower efficiency and a complicated encapsulation structure. Therefore, the Internet Engineering Task Force (IETF) proposed a more efficient IP data encapsulation technology which is called ULE. The minimum encapsulation header length is reduced to

[1] Corresponding author. Tel.: +86-10-62796691; fax: +86-10-62796691.
E-mail address:zz11@mails.tsinghua.edu.cn.

4Byte. In order to provide greater support to the transmission of IP data, ETSI proposed GSE encapsulation protocol in the DVB-S2 Technical Specifications. As compared with MPE and ULE, GSE can directly map the encapsulated data to the physical layer. It supports the encapsulation format of data packet of variable length. GSE is not only more flexible, but also greatly simplified.

2.1 Padding and Packing of MPE Protocol

MPE protocol is a main data encapsulation format currently used in satellite link IP data transmission. The encapsulation principle is shown in Figure 1. The IP packet is encapsulated into a Protocol Data Unit (PDU). Then, an encapsulation header with a minimum length of 12Byte and an encapsulation trailer with a minimum length of 4Byte are added to the PDU, thus forming a Sub Network Data Unit (SNDU). The final encapsulation is a MPEG-TS packet with a fixed length of 188Byte. Each TS packet has a fixed 4Byte header. Therefore, a TS packet can carry a payload up to 184Byte.

When a TS packet contains a data packet fragmentation header, an indication field shall be set in the first byte after the TS header, which is used to specify the location of the new fragmented packet. In MPE encapsulation process, padding or packing is used to handle the idle bits at the end of the encapsulation process. Packing has better efficiency than that of padding.

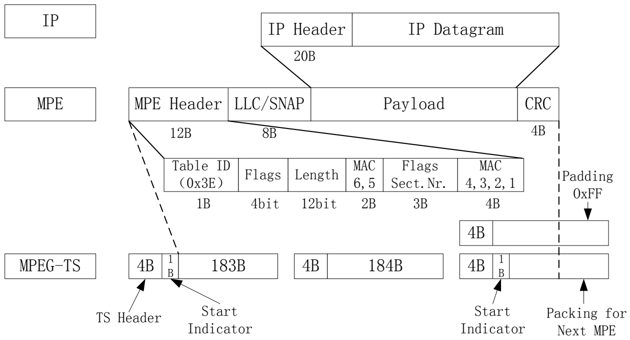

Fig. 1: MPE Encapsulation Principle

2.2 Padding and Packing of ULE Protocol

ULE encapsulation format is an optimization of MPE protocol. PDU is directly mapped to the packet transmission load, thus reduces the overhead and simplifies the encapsulation process. The major improvement of ULE encapsulation format is that the address field NPA in the header is set as selectable and the minimum length of ULE packet is reduced to 4Byte. The ULE encapsulation principle is shown in Figure 2.

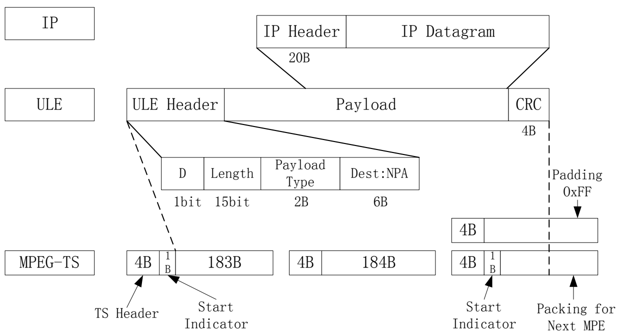

Fig. 2: ULE Encapsulation Principle

2.3 Packing of GSE Protocol

GSE is an encapsulation protocol designed by ETSI for DVB systems to provide greater supports for IP data transmission. The protocol gives up the format of fixed length TS data packet and uses the format of variable length packet. Moreover, GSE encapsulation maps directly to the physical layer transmission. GSE encapsulation header has a fixed length of 4Byte. The remaining fields are optional fields. Therefore, the encapsulation process is more simple and flexible. The GSE principle is shown in Figure 3.

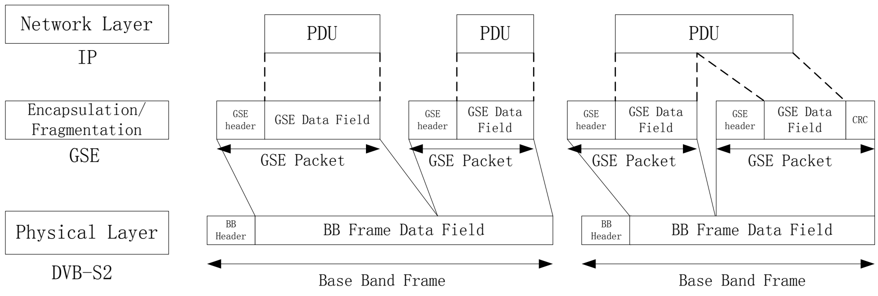

Fig. 3: GSE Encapsulation Principle

3. Comparison and Analysis of Efficiencies of Different Encapsulation Protocols

Performance of the three different encapsulation formats introduced in the above section can be calculated through a comparison of their efficiencies. Encapsulation efficiency can be obtained by using the following equation, that is, the ratio of the IP packet length before encapsulation and the total byte length after encapsulation:

$$\eta=\frac{L_{total,IP}}{L_{total,Encap}} \tag{1}$$

Assume N IP packets are encapsulated into M packets, the MPE and ULE encapsulation efficiency equation can be converted into the following equation:

$$\eta=\frac{NL_{IP}}{ML_{TS\_H}+PL_{SI}+NL_{SNDU}+L_{pad}} \tag{2}$$

Wherein, L_{TS_H} is 4B, LSI is the indication field for the new fragmentation data in the TS packet, L_{SNDU} represents the SNDU length after MPE and ULE encapsulation. L_{SNDU} is comprised of the encapsulation header, IP data and the packet trailer field. In which, MPE header length is 12B, ULE header length is 4B, including 4B trailer check byte. L_{pac} is the padding byte, which is 0 in packing mode.

In the GSE encapsulation process, the packet length is variable and the header length is also uncertain. For the convenience of calculation, let's assume that each IP packet is encapsulated in one GSE package and the minimum GSE header length is 4Byte. The simulation results are shown in Figure 4 – 5.

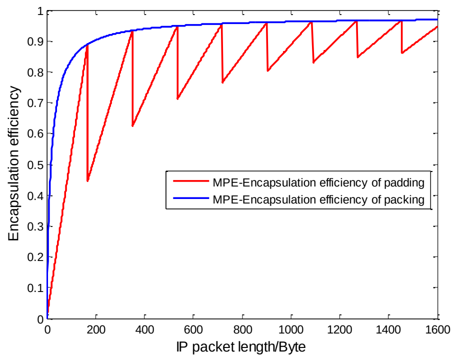

Fig. 4: Encapsulation efficiency of MPE Padding and Packing

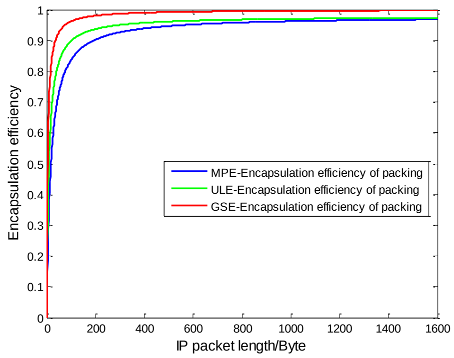

Fig. 5: Encapsulation Efficiency of MPE, ULE and GSE

As can be seen from Figure 4, the TS data packet is of a fixed length, the IP data packet is of a variable length. If the IP data packet can be encapsulated in TS packets of an integer number, the maximum encapsulation efficiency can be achieved. If the IP packet length increases 1B, a new TS packet will be needed for the encapsulation and the encapsulation efficiency will drop to the lowest level. If the remaining fields can carry new IP data packets, the encapsulation efficiency can be improved.

In the ULE encapsulation format, NPA field that indicates the destination address is set as an optional field. The shortest ULE encapsulation header is reduced to 4B, so the encapsulation efficiency is improved, especially in the encapsulation of shorter IP data packets. However, the ULE data packet must be finally encapsulated into TS packets for transmission, so performance improvement is limited, especially in the transmission of video and other long IP data packets. As shown in Figure 5, when the IP packet length is more than 800B, ULE encapsulation efficiency advantage, as compared with MPE, is no longer significant. The GSE protocol directly maps the encapsulated data to the physical layer transmission, so it can greatly reduce the redundancy bytes in the data encapsulation process and greatly improves the encapsulation efficiency. Moreover, because the GSE package length is variable and the encapsulation header design sets the indication field as optional, this encapsulation format has better flexibility and scalability. As compared with the other two encapsulation formats, GSE has significant advantages in encapsulation efficiency and encapsulation complexity.

Therefore, MPE is still the widely used encapsulation technology in current applications, but GSE encapsulation format will be used more and more in satellite network design process in the future.

4. IP Data Encapsulation in Star-shape Satellite Network Return Links

4.1 The Problem Arises

According to relevant statistics, in current satellite communication applications, more than 80% of the business is to happen between the central station and the remote terminal stations. Therefore, star-shape satellite network is the main form of practical application of satellite communications. However, the three main IP data encapsulation methods analyzed in the above section are put forward to solve the problems of downlink multiplexing between the central station and the remote terminal stations. These methods are not optimized for the IP data encapsulation in the return link from the remote terminal stations to the central station.

In an IP over Satellite system, routing between user terminals is completed in the IP layer and data transmission and addressing between satellite stations are completed in the link layer. The structure is shown in Figure 6. In a satellite downlink, the different transmission modes can be selected according to different transmission destination address, such as unicast, broadcast and multicast transmission modes. However, as shown in Figure 7 and 8, in return link transmission, the data transmission of a remote terminal station has only one destination address, that is, the central station.

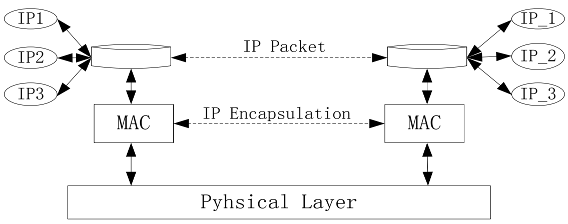

Fig. 6: IP over Satellite Routing and Addressing Mechanism

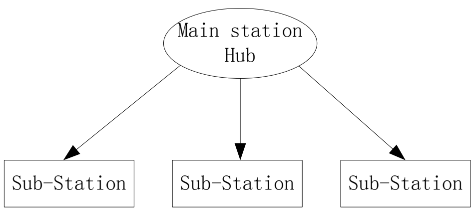

Fig. 7: The Central Station Downlink Transmission Topology

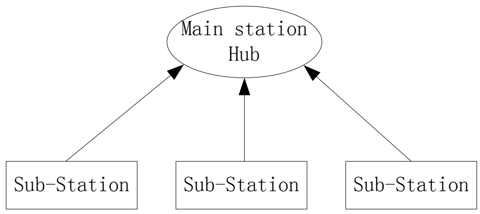

Fig. 8: Remote Terminal Station Return Link Transmission Topology

Through the analysis in the above sections, for all IP data packet encapsulation formats, destination address mapping is the main factor that influences the encapsulation efficiency. In the remote station return link of a star-shape network, the only destination address is the central station. When the central station receives IP data, it will send the IP data to the end user according to the IP address contained in the IP data packet. Based on this idea, for IP data transmission via remote station return link, the encapsulation format can be further optimized based on the GSE encapsulation.

4.2 IP Data Encapsulation Improvements for Upward Return Link

In satellite communication systems, downlink usually uses TDM multiplexing mechanism and signals are transmitted via downlink broadcast carrier to each remote station through statistical time division multiplexing mode. For the realization of unicast, multicast and broadcast transmission, special design is required for IP data encapsulation. For example, in GSE encapsulation protocol, an optional field "Label" is used to indicate data transmission routing information, as is shown in Figure 9.

S	E	LT	GSE Length	Frag ID	Total Length	Protocol Type	Label	Ext. headers
1b	1b	2b	12b	1B	2B	2B	3/6B	>=2B

Fig. 9: GSE Header Format

Satellite return link has multiple optional access modes, such as TDMA, FDMA etc.. Satellite communication network based on star-shape network structure is widely used in practical application. All remote station will send return link information to the central station.

GSE encapsulation protocol has higher efficiency and flexibility, but it can be further optimized when used in IP data transmission via SCPC satellite return link. Firstly, because IP data packet length is generally shorter than 1600B, one GSE packet can be used to encapsulate the IP packet. Secondly, in a star-shape network structure, the data transmission destination for all remote station is the central station, so the destination address indicator can be deleted. A source address indicator can be set for message discrimination. The structure is shown in figure 10.

PT	SID	PCK Length	IP Payload
1b	4b	11b	NB

Fig. 10: Return Link IP Data Encapsulation Format

Wherein, PT indicates the protocol type, which is used to represent Ipv4/Ipv6. SID is used to represent the system ID, which is assigned to the remote station by the system at the time of network login. PCK Length refers to the data packet length, the minimum encapsulation header length is reduced to 2B. The encapsulation efficiency is higher than that of GSE and the encapsulation process is more flexible and simple. The efficiency comparison with GSE is as shown in Figure 11.

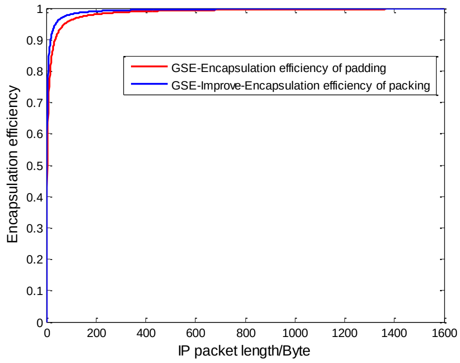

Fig. 11: Efficiency comparison of GSE and GSE-Improve Encapsulation

Although GSE encapsulation protocol has higher efficiency and flexibility, but it is an encapsulation mechanism designed to be compatible with many other encapsulation protocols. In practical network design process, we still have to make necessary improvement according to actual needs, so as to further improve the encapsulation efficiency, simplify the encapsulation process at the sending end and the unpacking process at the receiving end.

5. Conclusions

In this paper, the present three major satellite link IP data transmission encapsulation protocols are analyzed, including MPE, ULE and GSE. The protocol encapsulation efficiency comparison curve is drawn. The results show that, GSE protocol makes great improvement on encapsulation efficiency and encapsulation complexity. In IP data transmission in the uplink of a star-shape network structure, the routing information is quite simple, so the GSE protocol can be further optimized. To this end, this paper proposes a new encapsulation format for IP data transmission in satellite uplink of a star-shape network structure. As compared with GSE protocol, the new format has a more simplified encapsulation process and higher encapsulation efficiency.

6. References

[1] Wang Chunting, Zhang Junxiang, Pan Shenfu, etc. Satellite Communication System [M]. Beijing: National Defense Industry Press, 2012.

[2] ETSI EN 300 421. Digital Broadcasting (DVB); framing structure, channel coding and modulation for 11/12 GHz satellite service[S]. 1997.

[3] Fairhurst G, Collini-Nocker B. Unidirectional lightweight encapsulation (ULE) for transmission of IP datagram over an MPEG-2 transportstream (TS) [S]. Internet RFC4326,2005.

[4] ETSI EN 102 606. Digital Video Broadcasting (DVB); Generic Stream Encapsulation (GSE) implementation guidelines[S].2007

[5] LI Zhiyi, ZHAO Jianguo,YAN Jian Eff iciency analysis of IP over DVB encapsulation protocol [J]. Tsinghua Univ (Sci & Tech) . 2009, Vo l. 49, No. 8 .11 /39 : 1126-1130

[6] LUTZ E,WERNER M,JAHN A. Satellite Systems for Personal and Broadband Communications [M].Berlin Heidelberg:Springer-Verlag,2000.