Analysis Of Protocol Convergence For Satellite And 5G Communication

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Abstract. In recent years, with the commercial application of fifth-generation mobile communication (5G), the integration of satellite communication and 5G system has become a hot topic in the industry. The first thing to be considered in the integration of two communication systems is the integration and conversion of communication protocols between different systems. However, there is no final conclusion on how to integrate satellite and 5G communication protocol. By analyzing the differences and characteristics of satellite and 5G communication protocol, this paper creates a new protocol stack model from the direction of protocol system integration, and realizes the integration from the protocol level. According to the characteristics of different network applications, three network deployment modes are proposed. Finally, the application scenarios of satellite communication and 5G integration are given.

1. INTRODUCTION

In recent years, satellite communication has ushered in a new round of development boom in the world. The Fifth Generation Of Mobile Communication (5G) has also been put into commercial use. The integration of satellite communication and 5G has become a new hot topic in the industry. Due to the construction difficulties of ground network in some cases, full coverage can not be achieved. With the wide area coverage capability of communication satellite, the continuity of 5G service can be improved, especially in emergency, maritime, aviation communication and communication along the railway. The high transmission rate and low time delay of 5G network also enhance the user experience of satellite communication. Therefore, the integration of satellite communication system and 5G will give full play to their respective advantages, learning from each other's strong points to make up for their weak points, and jointly form a global seamless integrated communication network of sea, land, air and space to meet the various business needs of users everywhere, which is an important direction of communication development. [1]

As early as the 1990s, the research on the integration of satellite and ground mobile communication has not stopped. The first regional satellite mobile communication system in the world - North American satellite mobile communication (MSAT) system, which adopts the technology of simulating the ground mobile cellular network in the construction; Thuraya satellite communication system adopts the geostationary orbit radio interface (GMR) similar to GSM/GPRS system; The designs of the air interfaces of Iridium and Global Star system are based on GSM and IS-95; Skyterra system and terrestar system of the United States reuse the same frequency band by laying ground auxiliary base station satellite and base station, and the signal format of air interface is almost the same.
can switch seamlessly between satellite and ground base station, and users can enjoy 4G wireless broadband network without using dual-mode terminal. [2][8]

In recent years, with the development of 5G technology, a special standardization organization working group has been set up to study the standardization of satellite ground integration: the International Telecommunication Union (ITU) has proposed four application scenarios of satellite ground 5G integration, including relay to station, cell return, mobile communication and hybrid multicast scenarios, and proposed the key issues that must be considered to support these scenarios. According to the network architecture of satellite ground integration, 3GPP puts forward four construction models, analyzes and evaluates the relevant satellite access network protocols, discusses the establishment, configuration and maintenance standards of satellite terminals, and focuses on the seamless handover technology between satellite network and ground network. Sat5G alliance mainly focuses on network architecture, key technologies and simulation verification, business value proposition, etc. It plans to complete the seamless integration scheme in two and a half years, and carry out demonstration verification. In order to realize the plug and play of satellite communication and 5G, Sat5G puts forward six technical research pillars. The goal of the "5G satellite program" of ESA is to define the interfaces between 5G satellite components and other networks in the process of 3GPP standardization. Three research/work projects have been successfully submitted, and satellites have been listed as part of 3GPP R16. In China, based on the high-throughput satellite ChinaSat-16, China satellite communications completed the integration test of 5G data service transmitted by satellite in 2019, built the satellite base station backhaul test system by using the portable station of high-throughput satellite and 5G network, and realized the information transmission between 5G base station and core network based on satellite ground link. [3][9][10]

At present, the industry generally believes that there are two methods for the integration of the two: first, at the beginning of the design, the satellite communication network and 5G network adopt the unified air interface protocol, the space-based and ground-based network are managed and served in a unified way, and the terminal adopts the high integration and fusion design mode, so as to realize the seamless switching between the satellite network and 5G communication network through a single terminal; second, the satellite communication network as an access network is integrated into the 5G core network, which needs to complete the integration and conversion of the protocols of the two communication systems. However, how to integrate and convert has not been decided yet.

In order to solve the above problems, this paper designs a protocol conversion mechanism of satellite communication and 5G communication fusion to realize the fusion of satellite communication protocol and 5G communication protocol.

2. ANALYSIS OF EXISTING PROTOCOL SYSTEM OF SATELLITE COMMUNICATION

At present, DVB (digital video broadcasting) and IP over SDH (IP over SDH) are the main satellite communication protocols in the world.

2.1. DVB Protocol

The field of satellite communication started from DVB protocol broadcasting application, which provides broadcasting service for wide area and remote areas that can not be fully covered by optical fiber with its large bandwidth downlink service rate. With the development of satellite communication reverse link and broadband service, DVB standard is also updated. Today's DVB system standards are mainly enterprise standards formulated by satellite operators or product manufacturers, as well as a small number of industry standards and national standards. The standards formulated by international organizations are mainly DVB-S, DVB-S2, DVB-S2X and DVB-RCS/2. At present, DVB-S2X/DVB-RCS2 protocol is widely used.

2.2. IPoS Protocol

The outgoing direction of the IPoS protocol is based on the DVB-S standard, and the backward direction is the custom content of the IPoS protocol. In terms of transmission control mechanism, the
A combination of end-to-end solution of PEP and link layer solution is adopted in the IPoS protocol. The MAC layer control mechanism adapted to the satellite link is proposed fundamentally. Under the condition that the satellite physical equipment can only make limited changes, the simple and feasible control is completed, which has high error tolerance and survivability, realizes effective bandwidth management and reduces power consumption and the function of buffer capacity and improving channel capacity. IPoS protocol is a satellite network structure based on IP, which is the evolution and application of ground broadband IP technology in the field of communication.

The advanced nature of satellite communication system is mainly embodied in saving RF signal bandwidth and power, improving the quality and reliability of signal transmission. At present, in the field of satellite communication, most of the mainstream manufacturers follow the DVB protocol. This paper takes DVB-RCS2 as an example to analyze the protocol stack structure. The architecture of DVB-RCS2 protocol stack is shown in the figure below. It is mainly divided into high-level protocol and low-level protocol. Among them, the high-level protocol includes the application layer based on the application software and real-time running environment, and the middle layer to realize the interconnection between the application layer and the bottom layer; the bottom layer protocol is the key scope of the definition of DVB protocol, and also the layer that can best reflect the characteristics of the protocol, including the data link layer based on the logical control and MAC layer protocol, and the physical layer that defines the structure and parameters of the sending frame.

RCS2 protocol includes user interface (U-plane), control interface (C-plane) and management interface (m-plane).

The functional implementation of RCS2 protocol logically covers one or more layers of physical layer, link layer and network layer, as well as one of the user, control and management interfaces, as shown in the figure below.
User Plane Control Plane Management Plane

Higher Layers

Performance Enhancement Traffic Routing

Figure 2. RCS2 Functional logic diagram

Traffic Routing Performance Enhancement

System Control Antenna Control

Network Control Routing Control

Satellite Link Control Address Resolution

Traffic Routing System Control Antenna Control

SLA Management Accounting

QoS Control PEP Control

Fault Management Configuration &SWDL

Gateway station

Management interface SLA management function

Control interface Traffic control (C2P)

Network management center

Management interface User interface

End user Return channel satellite terminal Return channel satellite terminal End user

Management interface Control interface

Top management function

Figure 3. Functional structure of higher layers protocol stack in user, control and management interface

DVB-RCS2 high level protocol covers the management and control functions of terminal at high level, excluding physical interface or transmission equipment. [7]

The terminal is related to its high-level transmission interface, including satellite user and control interface, satellite terminal management and control interface, LAN user and control interface, and LAN terminal management and control interface.

The structure of high-level protocol stack is shown in the figure below.

DVB-RCS protocol higher level
The central station shares the satellite interface with the terminal, and has another physical interface and back-end interface. The back-end interface has high-level transmission interface, including back-end user control interface and back-end management control interface.

3. 5G COMMUNICATION PROTOCOL SYSTEM ANALYSIS

5G communication protocol is defined by IMT-2020 standard of ITU. The latest iteration of the standard is called 5G NR. 5G NR specifies two creative names: frequency range 1 (FR1) and frequency range 2 (FR2). FR1 covers the current spectrum as we know it: below 6GHz. This part of the electromagnetic spectrum covers everything from AM/FM radio to fast 5GHz dual band WiFi. New FR2 features include "millimeter wave" frequencies above 24GHz. This part of the spectrum is used to transmit data back and forth from satellites, for radar facilities along the coast, etc.

5G protocol includes control plane protocol and user plane protocol. As shown in the figure below. L1 and L2 are physical layer and data link layer respectively. On the network layer, the control plane uses SCTP protocol to encapsulate the control information, and the user plane uses GTP-U protocol to encapsulate the user data. At the same time, through the N1 interface, the terminal establishes an independent channel between the terminal and 5G core network, and uses NAS protocol to encapsulate and protect terminal control messages. [7]

![Figure 4. 5G control plane protocol stack](image)

![Figure 5. 5G user interface protocol stack](image)
4. INTEGRATION DESIGN OF SATELLITE AND 5G COMMUNICATION PROTOCOL

4.1. Overall Architecture Design
In order to realize the integration of satellite communication and 5G communication, it is necessary to connect satellite communication network to 5G core network. Firstly, the satellite communication terminal is connected to the hubway station through the satellite link, and the protocol conversion between the satellite and 5G is completed at the hubway station, and then it is connected to the 5G core network, so as to realize the integration of the satellite and 5G communication network.

![Overall architecture of satellite and 5G communication integration](image)

4.2. Protocol Architecture Design
It can be seen from the overall architecture that the key to the integration of satellite and 5G communication is how to complete the protocol conversion between satellite and 5G at the gateway station with minimal changes. Through the analysis of satellite communication and 5G mobile communication protocol system in the previous chapter, we can find that both protocol architectures are based on OSI seven layer model, and have their own characteristics in protocol system.

The satellite communication system represented by DVB system mainly defines the underlying transmission protocol. The GSE/RLE encapsulation format can flexibly adapt to different business types and data formats, and has higher transmission efficiency and lower link overhead. In terms of high-level protocol, the satellite communication system provides IP based flat transmission channel, which can create a pure two-tier network architecture according to the needs of users, which is suitable for private network isolation and self construction; it can also create a three-tier network, which provides IP based transmission tunnel, flexible access to user application platform, and various application scenarios. Most of the existing satellite gateway stations and satellite communication terminals are developed based on DVB protocol, and their equipment development is strongly coupled with satellite communication transmission system. [6]

The ground mobile system represented by 5G communication technology has a more complete protocol stack structure, the division of user plane and control plane, and the distributed deployment of core network elements, which effectively alleviate the hardware deployment constraints of communication network and increase the network flexibility. At the same time, due to the introduction of new technologies such as slicing, 5G mobile communication system has more abundant extensions on the network layer, which can provide users with richer business applications such as authentication,
conversation, multimedia and so on.

To sum up, this paper proposes a development idea of integration of satellite communication and 5G mobile communication. First of all, it starts from the direction of agreement system integration. By modifying the definition of communication protocol stack and creating a new protocol stack model, the integration is realized from the software protocol level.

Considering the characteristics of DVB protocol and 5G protocol, the protocol stack is divided into two parts: bottom layer and high layer. The bottom layer is mainly physical layer and link layer, and the top layer is regarded as high layer protocol. The integrated protocol stack can be designed with the idea of "bottom layer DVB + top layer 5G". The original protocol stack is divided into bottom layer (physical layer, data link layer) and top layer (network layer and application layer).

The underlying layer maintains the DVB protocol and the original GSE/RLE format for packet encapsulation. On the one hand, it can inherit the existing baseband and RF equipment, on the other hand, it can retain the advantages of DVB protocol with low channel overhead.

In the network layer, the existing DVB protocol is transformed. On the basis of IP protocol, 5G protocol is referred for protocol conversion. Specifically, SCTP/IP protocol conversion is performed for control plane information, and GTP-U/IP protocol conversion is performed for business plane data. Through data protocol conversion, the core interaction between satellite communication protocol and 5G communication protocol is realized.

The application layer is compatible with the existing 5G protocol, defines the air interface standard, and encapsulates the control information of the satellite terminal and the satellite gateway station by using the NAS protocol format, so that the air interface between the two has better security protection characteristics.

The modified protocol stack is shown in the figure below.

![Protocol Stack Diagram](image)

Figure 7. Communication protocol stack after protocol fusion

In the design of the system, the idea of fusion design is adopted only at the protocol level, and the protocol architecture based on DVB is still retained at the bottom layer. The satellite gateway station and the satellite terminal do not need to carry out hardware transformation, but only need to carry out adaptation transformation on the higher level protocol part, so that the satellite gateway station and the satellite terminal are compatible with 5G communication system functions. The schematic diagram of system transformation is shown in the figure below.
After the protocol fusion design of satellite and 5G communication, satellite communication network is used as the access network of 5G communication network to access 5G core network. Considering the deployment relationship between satellite gateway station and 5G ground core network, the network deployment architecture is designed and analyzed. According to different application scenarios, the deployment relationship between gateway and core network can be divided into three types.
4.2.1. The gateway station and the core network are deployed independently

![Diagram of Gateway Station and Core Network]

**Figure 10. Independent deployment diagram of Gateway station and Core network**

a) The control plane interface of satellite network is connected with AMF to transmit signaling messages such as mobility management and session management. The bottom layer of gateway station still adopts DVB protocol, and the upper layer performs protocol conversion in gateway station, which is converted into 5G protocol and then connected to the core network.

b) The service plane interface is connected with UPF to transmit the service plane message. After the message is transmitted to the gateway station, the protocol is converted to access the core network.

c) The SIP signaling message of voice service is transmitted to the P-CSCF of IMS through the user interface, and the voice data packet is sent to the called after the P-CSCF through the user interface. The called user can be the local user. At this time, the P-CSCF sends the voice packet to the local terminal through the user interface, or to the network of other operators. At this time, the P-CSCF sends the voice packet to the CSCF of other operators.

This deployment mode is suitable for the centralized management mode. Since there is no UPF service outlet in the local gateway, the service data of the gateway will converge to the core network outlet, which will increase the optical fiber transmission pressure between the satellite network and the core network.
4.2.2. The gateway station only deploys the user plane UPF of the core network, and the rest is separated from the gateway station

Figure 11. Schematic diagram of simultaneous deployment of Gateway station and core network UPF

a) Signaling messages such as mobility management and session management are transmitted to the control plane AMF of the core network for processing after protocol conversion at the gateway station;
b) The service plane interface connects with the UPF of the gateway station, transmits the service plane message, and completes the protocol conversion and export at the gateway station;
c) IMS voice service is transmitted to P-CSCF through the UPF deployed in the gateway station.

The deployment mode is suitable for distributed management mode, and UPF is deployed at the gateway side, which reduces the pressure of satellite network and 5G core network.
4.2.3. The Gateway station and the core network are deployed in the same place, and the Gateway station has complete the core network functions

Figure 12. Schematic diagram of simultaneous deployment of Gateway and core network

a) The interface of control plane connects with AMF, transmits signaling messages such as mobility management and session management, and performs protocol conversion directly at the gateway station.

b) The service plane interface is connected to UPF to transmit service plane messages, and the protocol conversion is directly carried out at the gateway station.

The deployment mode is suitable for the deployment mode of integrated gateway station. There is no mature 5G core network available in the application scenario. The construction of integrated gateway station includes 5G core network, and the base station can directly access the integrated gateway station core network.

5. INTEGRATED APPLICATION OF SATELLITE AND 5G COMMUNICATION

5.1. Uninterrupted network connection
The integrated satellite and 5G communication network can support users to switch seamlessly between satellite access network and 5G access network. Satellite communication terminals are installed on mobile platforms such as airplanes, ships, high-speed railways and automobiles, which can be connected to the ground 5G core network through protocol conversion after being connected to the ground gateway station, so as to maintain continuous and uninterrupted 5G network access service in the mobile process.

In the case of ground 5G network, first use the ground network communication, in the case of ground network can not be covered, the terminal can choose the satellite communication network to ensure the uninterrupted signal. That is to say, automatic switch and roaming between satellite and ground 5G network are realized.
5.2. **Broadcast distribution**
Using the forward broadcast characteristics of satellite communication, it can provide service distribution services for end users in a wide range, such as high-definition television. In daily situation, the ground 5G network can be used for broadcasting service distribution. When the amount of service information is too large and the ground network is congested, the satellite access network can be used to depressurize the ground network and carry out service diversion, so as to avoid the decline of service transmission capacity caused by single network congestion.

5.3. **Emergency communication**
In areas with weak ground network coverage, such as outdoor operation and field exploration, satellite access network can provide emergency communication means for users and realize small area network coverage. At the same time, in the case of earthquake, flood and other disasters, the ground network is damaged, the satellite access network can quickly build communication links, so that the site can quickly access the rear communication network. [3]

6. **CONCLUSION**
5G mobile communication and satellite communication, as the "two wings" of communication field, have their own advantages and disadvantages. Satellite ground integration has become an important direction of communication field. Starting from the fusion point of communication protocol system, this paper studies the characteristics of satellite communication protocol and 5G protocol respectively, creates a new definition of fusion protocol stack, and puts forward three fusion deployment modes and application modes, which provides construction suggestions for exploring the deep integration of satellite communication system and 5G mobile system.

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