A Cloud Service Architecture for SDN-Based Space-Terrestrial Integrated Network

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Abstract. With the development of communication technologies such as 5G, terrestrial networks have been able to provide efficient network services. However, the terrestrial network construction relies on base stations, which leads to the inability to achieve coverage in many areas of the world. To solve this problem, more and more researchers put forward the integrated network of terrestrial network and satellite network to achieve global coverage of the network. In this paper, we considered multiple factors and proposed a SDN-based cloud service architecture for space-terrestrial integrated network, which realizes the unified network management and provisioning through SDN. For the cloud service architecture, we introduce the components of the whole cloud service architecture in this paper, which are divided according to different levels and the functions of each part are explained in detail. Using the proposed cloud service architecture, different user requirements will be satisfied, and the quality of service is greatly improved.

Keywords: Space-terrestrial integrated networks · Cloud service · SDN · Architecture

1 Introduction

With the rapid economic development, the scope of human activities has spread all over the world. However, in remote areas such as mountainous areas and the sea, traditional terrestrial networks cannot achieve full coverage. Therefore, the communication requirements on a global scale cannot be met. In recent years, due to the rapid development of satellite technology, more and more satellites have been launched into space. The resulting space network provides many communication services for ground users, greatly facilitating people's production and life. But the existing satellite systems are isolated from each other. Without perfect space networks, the user demand of high speed, low latency and large connection cannot be met.

At present, many recently proposed studies combine space networks with terrestrial networks. With the global coverage capability of space networks, even in areas that cannot be covered by traditional terrestrial networks, users will obtain communication

Q. Guo et al. (Eds.): WiSATS 2021, LNICST 410, pp. 111–117, 2022.
https://doi.org/10.1007/978-3-030-93398-2_11

services by directly accessing space networks. However, it is not easy to construct and manage a space-terrestrial integrated network formed by space networks and terrestrial networks. The rapid topology changes, long transmission delay, and high heterogeneity between satellite network and terrestrial network all make the existing network architecture unable to achieve networks cooperation.

To solve this problem, a cloud service architecture for SDN-based space-terrestrial integrated network is proposed, which realizes global communication services. In this architecture, the SDN controller performs unified scheduling of space network and terrestrial network, and collects information from them in real time. Thus, it realizes networks cooperation and provides better quality of experience.

2 Related Work

The concept of an integrated space-terrestrial network is based on terrestrial network and integrates the space-based network into the existing terrestrial network to form a unified and efficient interconnection network [1]. From the development point of view, early integrated network was constructed by GEO satellites [2]. GEO satellites have a large coverage area and only need fewer satellites to achieve global coverage, but their transmission delays are large, which cannot provide real-time and efficient services for delay-sensitive applications. As a result, the current satellite network mainly relies on the satellite constellation composed of LEO satellites as the access network to provide services [3]. From the perspective of public demand, the literature [4] elaborated on the development of satellite constellations and proposed network slicing technologies for different service characteristics to achieve flexible message forwarding. The literature [5] analyzed the current situation of integrated network construction. From the composition of space-based networks and terrestrial networks, the research summarized the current development of domestic and international networks and pointed out the direction for future development. To achieve the integration of various heterogeneous networks, the literature [6] pointed out the problems of dynamic routing, link exposure, and time-varying topological information faced by the integrated space-terrestrial network and proposed future research priorities. Now, most of research consider combining SDN technology to achieve deep network integration. For example, in [7], the network architecture consisting of SDN/NFV was proposed, and the dynamic management of the network and the efficient use of resources were analyzed in detail. The literature [8], to improve the efficiency of the current network management, a new STIN architecture was proposed to satisfy the rapid retrieval of information by different users. The literature [9] combined with railway operation examples, in order to solve the practical problems such as poor railway communication signals and slow data transmission, an air-sky network fusion scheme for railway systems was proposed. To address the problem of efficient routing in networks, the literature [10] provided a detailed analysis of routing policies and described the various challenges of achieving efficient routing in networks. The literature [11] presented a comprehensive overview of different satellite communication networks, focusing the research on the physical layer for the problem of exposed satellite communication links that are vulnerable to eavesdropping, and detailing the security techniques currently used in the physical layer. The literature [12] proposed a H-STIN network architecture based on the current development of the Internet of Things. It combined mobile and satellite networks, and a comparative analysis of the different communication protocols that are still available. The literature [13] pointed out the development trend of the future network, combined with different application scenarios, explained the key technical need to be solved, and put forward corresponding suggestions. To improve the utilization of space-based information, a space-based information application service system based on cloud architecture was proposed by [14]. It introduced the overall composition of the system and explained the specific role of each part. However, the above paper only considers certain aspects and lacks an explanation of the overall structure. In this paper, we analyze the composition of this network from a holistic perspective, and then introduce the cloud service architecture, explain the functions of each layer.

3 The Space-Terrestrial Integrated Network Architecture

The space-terrestrial integrated network architecture is composed of three parts: the space-based backbone network, the space-based access network, and the terrestrial network. The structure is as shown in Fig. 1.

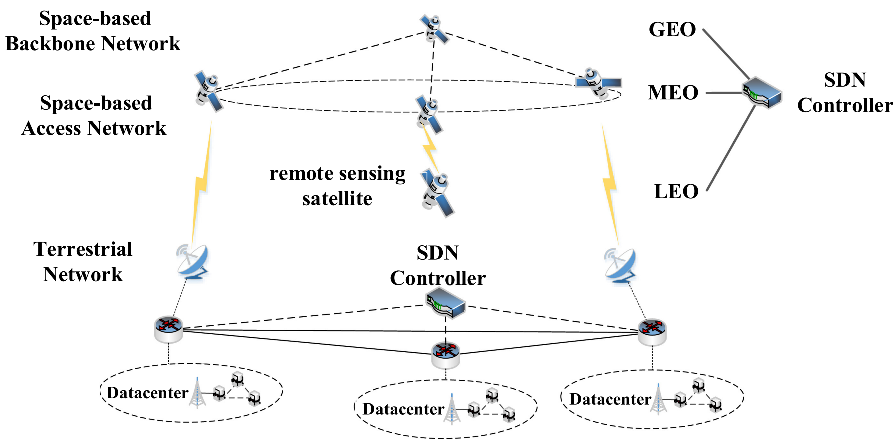

Fig. 1. The architecture of the space-terrestrial integrated network

3.1 SDN-Based Heterogeneous Network Convergence Architecture

This section focuses on the role of each heterogeneous network in the overall network architecture.

The Space-Based Backbone Network. The space-based backbone network consists of GEO satellites, which interconnected by a laser link. It is responsible for connecting the satellite nodes in the network and can be used as the SDN controller, which analyzes and forwards the commands issued by the ground data center and transmits commands to the MEO/LEO orbiting satellites. In addition, with the large storage and computing capabilities of GEO satellites, it maintains the flow tables in the network and manages all flow tables. When a data packet comes in from the ground data center or space-based access network, the data packet can be routed to the designated location according to the stored flow table information. For different QoS requirements, the space-based backbone network can also choose to forward the incoming data after preliminary processing, which effectively reduces the load on the link and improves the quality of service.

The Space-Based Access Network. The space-based access network is mainly composed of MEO/LEO satellites. Compared with GEO satellites, medium-low orbit satellites are closer to the ground, have lower transmission delay, and less information loss during transmission. Therefore, it is a suitable choice for the space-based access network. The LEO satellites are composed of communication, navigation, and remote sensing satellites. The geographic location, weather conditions and other information of the access user collected through the satellite provide the access user with appropriate channels and network resources to maximize the use of resources rate. At the same time, the MEO/LEO satellites can act as switches for the entire SDN architecture. After a user accesses it, different data packets are distributed according to the command of the SDN controller.

Terrestrial Network. The terrestrial network consists of the existing cellular network, mobile Wi-Fi, which together with the satellite network forms a communication network with global coverage. It is interconnected by optical fiber links to form a unified data center in which data can be forwarded and stored. To facilitate the management of the integrated network, the SDN is used to separate the control plane and the data plane, and operations such as the distribution of the flow table are realized through the SDN controller and the OpenFlow protocol. NFV technology is also used to map the network resources into a virtualized resource pool, and the network is managed uniformly through the SDN controller to realize real-time monitoring and control of the network status. Based on the information monitored at different moments, the SDN controller can dynamically adjust the network resource allocation policy, routing path selection and realize the dynamic configuration management of the network.

3.2 The Space-Terrestrial Integrated Cloud Service Architecture

To fully utilize and share the information resources of the above-mentioned networks, with the help of virtualization, cloud computing and other technologies, the terrestrial network and space network resources are integrated, with a view to providing various users with personalized service content and improve the overall service quality. This section introduces the components of the Space-Terrestrial Integrated Network Cloud Service Architecture and describes their corresponding functions. The structure is as shown in Fig. 2.

Infrastructure Layer. The infrastructure layer contains a variety of bare metal, which mainly includes the real physical devices such as computing, storage, and network of each space-based node and ground-based node. Relying on the cloud service

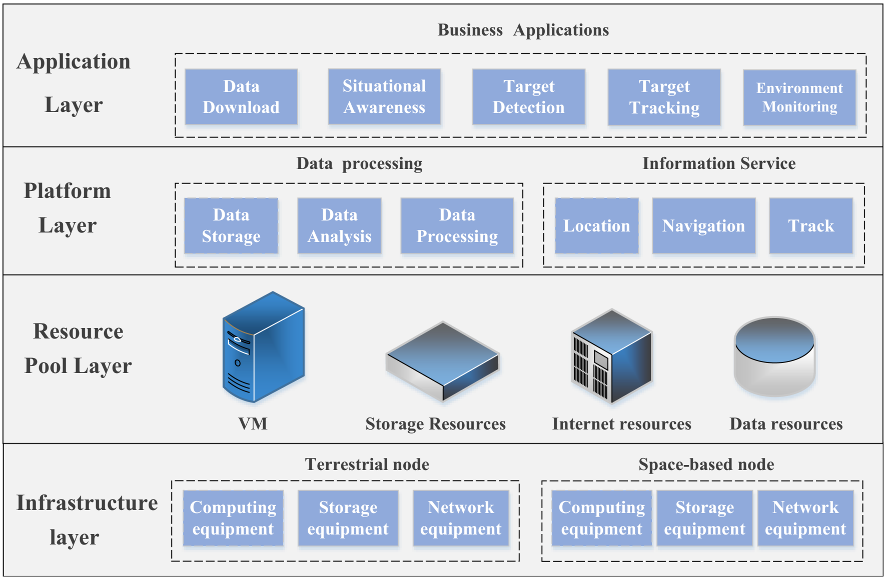

Fig. 2. The architecture of the space-terrestrial integrated cloud service

architecture to form a unified hardware device, it achieves efficient management of each device. As the lowest part of the cloud service architecture, the infrastructure layer provides basic hardware support for the various functions of the entire cloud service, ensuring that the cloud service platform can run stably and efficiently.

Resource Pool Layer. The resource pool layer contains virtual machines and containers. It adopts virtualization technology to virtualize the hardware devices of the infrastructure layer and abstract it into a virtualized resource pool, forming a resource pool layer where each real physical resource can be configured and managed to achieve efficient, stable, and flexible device configuration. It provides the appropriate device resources for different user needs, while providing support for data processing, storage, analysis, and other operations at the platform layer.

Platform Layer. The platform layer manages virtualized resources and provides users with basic communication services. With the help of the powerful computing and storage capabilities of the ground data center, it can also realize the storage of multi-source data of all terrestrial networks and space-based networks, and comprehensively process these data to provide users with intelligent services. According to the status, intelligent decision-making is adopted to improve the resource utilization rate of the whole system and reduce the network congestion rate. The processing of data at the platform layer includes the processing of various data such as radar images, navigation data, geographic location information, and weather conditions to form effective basic information. It is classified and managed in a reasonable manner to provide effective information services to the users.

Application Layer. The application layer provides customized applications for users in different industries based on the processed information modules provided by the platform layer combined with different algorithms. Users can access different applications online and obtain services such as navigation, positioning, tracking, and monitoring of specific targets through the encapsulated software interface formed by secondary development. This enables quick access and efficient services for all types of end-users, making the cloud service architecture available to meet the different needs of users.

4 Application Scenarios

The space-terrestrial integrated network has a wide range of application scenarios because of its large network capacity and communication is not restricted by natural conditions such as terrain. It realizes the global coverage of communication network. With the help of satellite network, it effectively compensates for the shortcomings of insufficient coverage of terrestrial network, making it possible to provide network services to users in areas where terrestrial base stations cannot be deployed, such as oceans and deserts. And when encountering natural disasters such as earthquakes and mudslides, even if the ground network is destroyed, the satellite networks are still available to realize the communication, navigation, and other services to the disaster area. In addition, with the increasing popularity of mobile communication devices, people nowadays rely more and more on mobile communication devices such as cell phones. However, currently on high-speed trains, airplanes, and other means of transportation, due to various conditions, it cannot provide efficient Internet services. With the help of the integrated network, this problem can be effectively solved, and a better quality of experience will be provided on the journey.

5 Conclusions

Based on the existing satellite network architecture and terrestrial network infrastructure with SDN technology, this paper presents rational integration of cloud services architecture to achieve seamless coverage of satellite-terrestrial network. At the same time, virtualization technology is used to map the calculation, storage, and network resources in the network into a unified resource pool, which realizes the comprehensive management of heterogeneous network resources. On this basis, a platform layer and an application layer are built to process multi-source information and provide convenient application services for different access users.

Acknowledgement. This work was supported in part by the National Key Research and Development Program of China under Grant 2020YFB1807900, in part by the Aeronautical Science Foundation of China under Grant 2020Z066050001, and in part by the Fundamental Research Funds for the Central Universities under Grant N2116013.

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