Research on the Integration Demonstration System of Space Information Network Based on TDRSS

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ABSTRACT Aiming at demonstration of space information network, this paper proposed the integration demonstration system based on TDRSS, which can make up for the difference of transport protocols, operation mode and data distribution between space information network and TDRSS. The system expanded the topology structure of TDRSS in order to be compatible with space information network service and supply the theoretical and technical base for the improvement of space information network.

1. INTRODUCTION
Space information network is the network system that can acquire, transmit and process space information using space platform as carrier, such as satellites, near-space balloons, planes and so on. Now space information network is the global research hotspot [1] [2]. As the depth and range of theoretical research on space information network is developing sustainably, we need an open demonstration platform for the theory and technology research in order to establish quantitative knowledge of space information network and improve the developing of research. As a result, the integration demonstration system of space information network is a significant research area now [3].

As an integrate system in orbit, TDRSS is similar to space information network to a certain extend on the structure, function and service objects, which can provide feasible method to the demonstration of space information network [4]. The design proposal of demonstration system based on TDRSS was proposed in this paper, in which the open and flexibility of TDRSS was utilized to illustrate space information network. The proposal can supply a restructurable and expandable demonstration platform to accelerate the development of space information network in the future.

2. STRUCTURE OF SPACE INFORMATION NETWORK
According to the transmission requirement of space information network and the main characteristic of transmission platforms, the space information network has two-layered architecture consisting of backbone layer and regional access layer [1], as shown in Fig.1. As the core of the space information network, the backbone layer should satisfy the requirements such as global overage, stable structure, wideband carrier capacity, convenient access, supporting multiple types of service access and interconnection of heterogeneous networks. The service enhancement layer is composed of the systems which have the relative simple functions, but can provide regional coverage. The service enhancement layer mainly aims at the non-spacecraft users and improving the regional information transmission capability. It achieves the rapid information transmission among different users in the same region by establishing the regional network. As the access terminals of space information...
network, users are the originator of transmission services, and the end to end transmission can be performed through the transmission channel provided by space information network. Users could be the information acquisition and application platforms, such as the spacecrafts, planes, ships and the relevant ground application centers. Users can implement the convenient access to space information network through the backbone layer and service enhancement layer.

Figure 1. Space information network structure

The two-layered space information network has an open structure, which is compatible with different types of access subnet. The backbone layer is consisted of GEO satellites and relevant ground system, which has the advantage of stable structure. There are different types of service provided by the space information network, such as wideband data transmission service of single user, narrowband data transmission service of single user, trunking communication of multi-user in a group, data transmission service between groups. Divided by the movement characteristic of users, there are predictable trajectory services and unpredictable trajectory service. Divided by relay requirement, there are real-time service and non-real-time service. Divided by the access way, there are planned service and burst service.

3. DEMONSTRATION SYSTEM OF SPACE INFORMATION NETWORK

As an enormous system, the space information network can provide different data transmission services for different users. But there are many key techniques to be solved, such as networking protocols, transmission techniques and so on. This paper proposed an integrated demonstration system based on TDRSS, which can provide the proof platform for key techniques.

3.1 Introduction of TDRSS

TDRSS is a geostationary satellite system, which can provide the space-based measurements and data transmission for the global LEO satellites and can get nearly Gbps transmission rate. We can see from the structure that three TDRS can get global coverage. Through the ISL and satellite-to-earth link, TDRSS can be connected with LEO satellites and ground stations. The connectivity between different LEO satellites can be realized through TDRS and ground stations. Thus the structure has partly the characteristic of network, which is shown in Fig. 2.

On the other side, the characteristics of TDRSS such as high dynamic tracking and bending transmission are convenient for the reengineer of network protocols and technique proof, which is very helpful for the realization and demonstration of system opening, expansibility and reconstruction.
As a conclusion, TDRSS is similar to the space information network in the system structure, system function and service objects. And the successful application experience of TDRSS on different user platforms can provide feasible method for the comprehensive integration demonstration of key techniques of space information network. But compared with the service feature of space information network, there are some differences between TDRSS and space information network, which are given below.

3.1.1 Protocol difference
The transmission protocol of TDRSS is special designed for it, which can not provide interconnection between heterogeneous networks. In the transmission protocol of TDRSS, the data transmission is operated on the data link layer, while the ground station of TDRSS and the user center must pack, extract and distribute the forward data and reward data on the application layer. According to the transmission protocol, the data from space to ground can not be routed and switched directly. As a result, the space target can not be connected with the ground system directly on the network layer and the protocol conversion of data will increase the processing delay and complexity of system.

3.1.2 Operation difference
TDRSS strictly operates as the operation plans which are planned several days ago. Usually, the users of TDRSS must submit the request a week ago. And the control center of TDRSS will accomplish the resource allocation and decide the operation plans of TDRSS. Since the operation plans are decided, there is no much room for the users to adjust working plans. This kind of strictly planned operation mode can not be used to the quick access of the space information network.

3.1.3 Control difference
TDRSS distributes data from a storage point in the control center, which is inflexible to the users. The data of LEO satellites transmitted through TDRS to the ground station must be received all by the control center of TDRSS and retransmitted to the users after protocol conversion. The data distribution method has too many segments. As a result, when the number of users and the amount of data increases, the control center of TDRSS as the storage and retransmit point will bear more and more pressure on the reliability and data distribution capability.

3.2 Design of demonstration system
Aiming at the difference of transmitting protocols, operation mode and data distribution method between the space information network and TDRSS, the design of demonstration system was proposed in this paper.
3.2.1 Transporting protocols
According to the IP connection demand of space and ground, a system composed of LEO user satellites, TDRS, ground station, control center and the user data centers was proposed, which is illustrated in Fig.3.

![Figure 3. Data Relay Transmitting system structure based on IP connection](image)

3.2.1.1 LEO user satellites with multi IP address
As for the LEO user satellites, there is subnet in the users. In order to transmit the subnet data, a gateway is designed to complete the protocol conversion from data link layer protocol of subnet to the data link layer protocol of space channel, for example the CCSDS AOS protocol. After the data is transmitted to ground through the TDRS channel, a gateway in the ground station is also designed to extract IP message from the data link layer protocol of space channel and accomplish the protocol conversion from the data link layer of space channel to the data link layer of ground network. After the protocol conversion, the standard routing equipment will distribute the data to the user data centers according to the destination address in the IP message of the space subnet. Thus the routing path can go through the control center or not as needed.

3.2.1.2 LEO user satellites with single IP address
The user satellites with single IP address has no subnet, so the link layer protocol conversion inside the user satellites is not necessary. We can directly package the IP message into the data link layer protocol of space channel and transmit through the space channel. The other processes of transmission are the same with user satellites with multi IP address.

According to the lately research result of space data transmission protocols, the protocols which combined the IP and CCSDS protocols were adopted in our system, as shown in Fig.4. The data link layer protocols of ground network and subnet of user satellites adopted the data link layer protocols of Ethernet and 802.11 wireless network. In the space channel, the SDLPs of CCSDS were adopted. Because the data link layer protocols of ground and space are different, the protocols conversion must be accomplished before transmission through ISL channel and SGL channel. In the network layer, we adopted the standard IP protocols. Aiming at the reliability and efficiency of transmission, the transport layer not only adopted the standard TCP/UDP protocols but also adopted the segmented techniques of TCP to improve the performance of transport layer. The segmented techniques of TCP can overcome the long link delay of transmission, the high error rate of network and unsymmetrical link bandwidth and so on. The application layer can adopt many standard protocols such as HTTP, SMTP, FTP, Telnet and so on, or the users can design special application layer protocols according to their requirements.
3.2.2 Operation mode driven by tasks
In order to improve the flexibility of resource application and adjustment of TDRSS, an operation mode driven by tasks was proposed which can dynamically adjust the resource of TDRSS according to the tasks requirements of users [5]. After the resource applications were received by the control center of TDRSS, the system can adjust the resource assignment rapidly and automatically and the difference between new allocation plan and old allocation will be minimized in order to minimize the disturbing to other users. In the operation mode driven by tasks, the flow of resource adjustment of TDRSS was given in Fig.5. First the insert resource requirement was preprocessed by the dynamic adjustment algorithm, which can calculate the TDRSS resource that can supply the demand.

3.2.3 Networking receiving and sharing system on ground
As the transmission pivotal of all kinds of different user platforms, a networking receiving and sharing system was designed in this paper. In the system, the different kinds of user data can be stored and shared in order as needed, which can be the base of the massive data sharing of space information network in future [6]. The system adopted the structure of universal platforms and special plug-ins, which was composed of data receiving, data reprocessing and resource sharing service, as shown in Fig.6. The data receiving system can receive and store user data in real time. The data reprocessing system can decrypt, analysis and decompress the user data according to the user demands. The special processing plug-ins can be added to the system to do further processing such as multi-frame imaging, radiometric correction, geometry correction and so on. The resource sharing service system can store, organize and manage the data universally and supply data catalog search and download to users.

4. CONCLUSION
Aiming at the spaces information network structure, this paper designs the demonstration system based on TDRSS, which is composed of data relay transmission system through IP connection between space and ground, operation mode driven by tasks and networking receiving and sharing system on ground. The demonstration system can provide the verify platform for the research of key techniques in space information network and improve the development of theories and techniques research.

REFERENCES
[1] Zhang Wei, Zhang Gengxin, Gou Liang, J. 2016. Satellite Constellation Design in Space Information Network In ZTE Technology Journal. 19-23,45.
[2] Liao Yong, Fan zhuochen, Zhao ming, J. 2017. Survey on Security Protocol of Space Information Networks In Computer Science. 202-204.
[3] Zhou hongbin,Yin bo, J. 2016. Research on Spatial Information Network System Validation Technology In Radio Communications Technology. 16-19,47.
[4] Ji Wenlong, Yu Xiaohong, J. 2014. Analysis of Development and Application of Foreign Data-relay Satellite Systems In Journal of Sichuan Ordance. 118-120,124.
[5] He chuan, Li Yajing, Qiu Zhen, J. 2017. Task programming models and algorithms of tracking and data relay satellite in application-on-demand In *Chinese Space Science and Technology*. 46-55.

[6] CHEN Hao ZHAI Zheng'an GAO Shenghua ZHANG Bin, J. 2016. Design of Ground Cloud Storage Structure for the Tracking and Relay Satellite System In *Chinese Space Science and Technology*. 392-399.