Development and Trend of Space-based Information Network

Zhenhua Liu¹, Chuanwen Lin¹* and Gang Chen²

¹HeFei University, HeFei, AnHui, China
²People's Liberation Army 75837, Guangzhou, China,
*Corresponding author’s e-mail: lincw11@foxmail.com

Abstract. With the development of space-based technology, the construction of the space-based network has been into a period of major change, countries are putting forward their own space-based network and getting them off the ground. This paper analyzes the space-based network development situation, introducing the SCaN network in the United States, Europe ISICOM plan and the development of China's SGIN, discussing the trend of the development of the space-based information network. At present, the construction of space-based network is still based on the foundation network as the core, the space-based system as the expansion, based on the communication interruption satellite, gradually evolves into the space-based network, in the future it will integrate the space-based navigation, space-based information acquisition to form a space-based integrated information network.

1. Introduction

With the increase in the number of spacecraft communication satellites, data relay satellite, navigation satellite, and sensing satellite are independent of each other. The "chimney" architecture is increasingly detrimental to the exchange, integration, and sharing of information. On the one hand, each system is constructed to solve different purposes, the mutual compatibility and interaction capabilities are poor, and information cannot be quickly and efficiently transmitted. On the other hand, the construction of each system requires its own measurement and control system and information processing and exchange facilities, which inevitably causes repeated construction and cost waste.

It is difficult to maximize the effectiveness and advantages of space-based systems. In this context, countries have begun research and attempted to interconnect different types of space-based systems and build networks. The space-based network interconnection plans have been proposed one after another, taking the lead in attempting from various aspects such as basic concept research, key technology research, and preliminary practice.

In the military field, the United States proposed the concept of a transformational communication system to achieve network interconnection from the perspective of traditional space-based systems; in the civilian field, NASA proposed the concept of the interplanetary Internet to try to move the ground-based Internet to space; in the commercial field, Europe proposed ISICOM plans to gradually build a space-based integrated information network through incremental construction. China has proposed the SGIN (Space-ground Integration Information Network) plan. Although the space-based networks proposed by various countries currently have many differences in terms of network topology, network composition, and construction methods, the interconnection of space-based systems has become a consensus, and the development of space-based networks is a general trend.
2. Development of Space-based Information Network Systems

With the development of satellite communication technology, all countries have proposed space-based network plans. The systems that have been planned and under construction include the SCaN network in the United States, the ISICOM project in Europe and the SGIN system in China.

2.1. SCaN Network

NASA authorized its Space Communications and Navigation (SCaN) office in 2006 to be responsible for the unified management and integration of its space communications and navigation network and infrastructure, and to deploy and upgrade the "Integrated Space Communications Network" for SCaN [1-2]. It planned to build and maintain a scalable, integrated mission support infrastructure that can quickly integrate new technologies while providing comprehensive, robust, cost-effective, and higher transmission rate space communication services. SCaN network construction is divided into 4 stages, and the system has different performance and characteristics at different stages as shown in Table.1.

Table 1. SCaN network construction plan

| Network Construction                      | Performance and Features                                                                 |
|------------------------------------------|------------------------------------------------------------------------------------------|
| Original network stage (2010)            | Consists of 3 original independent networks                                              |
| Pre-integrated network stage (2015)      | The three original independent networks are still independent, but added some new features to lay the foundation for the next stage, including standard services and interfaces; |
| Integrated network stage (2018)          | The original 3 independent networks integrate an integrated communication and navigation network system structure, providing space Internet services and unified and standard services for space vehicles; |
| The post-complex network stage (2025)     | The comprehensive information network is further expanded and new technologies are introduced to meet the needs of NASA's long-term exploration and scientific research |

Currently, NASA's SCaN network consists of independent space networks, deep space networks, and near-Earth networks. Fig.1 shows the current physical form and network architecture of the SCaN network. Services provided to various users are uniformly provided by NASA Integrated Services Network (NISN). Among them, the space network includes TDRS (tracking and data relay satellites), using three orbital positions to achieve comprehensive coverage of various orbits around the world, and other satellites are mainly used to enhance services. In addition, the space network also includes three ground receiving stations deployed in Baisha and Guam, equipped with a TCP/IP data interface service capability system, enabling users to send command data and receive telemetry data using the TCP/IP protocol. In terms of task scheduling, it first needs to establish a user database in the network control...
center data system to record key information such as user platform parameters, requested service types, and user authorization, and then perform operation management and scheduling of satellite resources. Event scheduling, forecasting scheduling, activity scheduling, scheduling conflicts and scheduling support, etc..

2.2. ISICOM Network
After breakthroughs in inter-satellite links and key basic technologies, the European industry proposed the ISICOM (Integrated Space Infrastructure for Global Communication) concept in 2007 [3], and planned to develop IP-based, large-scale microwave and laser links. The capacity interstellar Internet connects space communication, navigation, and earth observation satellites to the ground communication network to form a huge communication network integrated with the earth and the earth, and provides various Internet and IoT applications for government agencies, enterprises, collectives and individuals. As shown in Fig.3, ISICOM not only needs to be fully integrated with the future global communications network, but also provide value-added services by complementing Galileo and GMES systems.

Figure.2 ISICOM system Architecture diagram

ISICOM has four main tasks: ① Improving the coordination of security forces and maintaining peace and stability in Europe: The challenges and difficulties faced by this task include confidential communications, protecting networks from terrorist attacks, and interoperability. The required capabilities are: Two-way mobile communication and confidential data links; ② Improving disaster management and mitigation capabilities through globalization and deployment of robust communication systems: Challenges and difficulties faced by this task include communication bandwidth, data rates, delays, services, and universal coverage and interoperability requirements, the ability to be able to quickly reconfigure the capacity of the beam in the disaster area, two-way mobile communication; ③ Provide coordination and communication services for the GMES and Galileo systems: this task has no clear challenges and difficulties, it needs to have data relay capabilities; ④ Providing universal access to ICT services for EU citizens: Challenges and difficulties faced by this task include broadband capacity, universal coverage, integration with new communications and broadcasting technologies, integration with terrestrial networks, and interoperability, Required capabilities include high-speed Internet industry in Ku / Ka band Provide the next generation of broadband access, the next generation mobile communication 4G bidirectional evolution of the next generation of DTH / Digital Multimedia Broadcasting (DTH / DMB) system.
2.3. SGIN Plan

In 2006, academician Rongjun Shen first proposed space-ground integration information network [4], which aims to establish the interstellar Internet covering the solar system. Academician Manqing Wu and others gave a more specific definition of the system architecture for SGIN [5], which is combined with the application requirements and further started the upsurge of the research of network architecture [6-7]. In recent years, a lot of research has been conducted on protocols and network security [8-10].

With the development of research, the definition of SGIN is evolving. At present, SGIN is formed by the interconnection and integration of heterogeneous networks such as space-based backbone network, space-based access network, and ground-based node networks, including ground-based networks, terrestrial Internet, and terrestrial mobile communication networks. It adopts a unified technical system and Standard specifications, as shown in Fig 3. The space-based backbone network and ground-based nodes are interconnected via satellite-to-ground high-speed microwave or laser, and the space-based access network is connected to the backbone network through microwave or laser communication links to achieve wide-area communication and inter-network interworking.

![Figure 3 Architecture of Space-ground Integration Information Network](image)

The space-based backbone network is composed of several GEO satellites or clusters of satellites, these satellites are interconnected by high-speed inter-satellite link; the space-based access network is composed of several LEO satellites, with inter-satellite links between satellites. Large-span interconnection can also be achieved through space-based backbone networks. The ground-based node network is composed of ground operation control stations and ground fiber.

3. Development Trends of Space-based Information Networks

3.1. With ground network as the core and space-based system as the extension

Currently, the space-based information network attach great importance to the construction of ground networks, because many network-related functions, including routing and switching, network management, etc., are easier to implement on the ground. In addition, the availability of terrestrial networks and the availability of key geographical locations must also be considered. For example, the United States has established multiple military bases around the world, so it can expand its local network.

In order to achieve the interaction between internal systems and interaction between systems, the ground network is usually required for transmission and processing, which is difficult to achieve with space-based systems alone. For example, the battlefield situational awareness information (including images and video) obtained by the United States requires transmission of multiple satellites to the Middle East front, which may require satellites in the Pacific and Indian Oceans. Since these satellites
cannot be directly connected, ground stations may need to be established in Australia or Japan to enable information transmission between the satellites. In this way, information transmission requires at least two hops, and the transmission delay is greatly increased. Whether it is a government / military satellite communications system or a commercial satellite system, terrestrial networks are an important infrastructure. For example, the United States has established terrestrial telecommunications ports worldwide through DISA and military and commercial satellites worldwide through fiber optic connections. Although Intelsat serves global governments and commercial users, its ground-based optical fiber network (Intelsat-1) is also one of its core competitiveness. In cooperation with space segmented satellites, 14 core routers have been established in three regions of Asia Pacific, the Americas and Europe to expand its terrestrial network to all parts of the world.

3.2. Tracking & Data Relay Satellites play a core and basic role in it

Regardless of the development status or advanced research plans, Tracking & Data Relay Satellites (TDRS) are the foundation of space-based information networks. TDRS usually need to connect to other space nodes and ground networks. They are not only the core of space-based routing and switching, but also an important means of connecting other types of satellites. They will become the key to future space-based information networks.

From the perspective of functions, TDRS are the main transmission channels, the key to achieving high-speed transport, and an important support for the effective use of information. Therefore, it should be considered as the core infrastructure of the spatial information network. Other networks, systems, and nodes are based on this communication infrastructure and then execute various applications.

Judging from the development plans of space-based information networks in various countries, this has also been fully reflected. In the interstellar Internet, the high-speed interconnection backbone network is the basis for the interconnection of all spacecraft and all systems. The constellation or formation and the adjacent network are interconnected through the access network and the backbone network. In the Global Communications Integrated Space Infrastructure Plan, although different nodes and satellites in different orbits have certain communication capabilities, they still need to rely on GEO and some non-GEO TDRS as the basis for implementing earth observation satellites, navigation satellite, land, sea and air users.

3.3. Comprehensive information networks are a trend

From the perspective of related research plans, the space-based information transmission network will no longer be a model of independent construction and independent development. It must fully consider the needs of other network users and coordinate with their construction. The integration of information transmission networks and information acquisition networks will be further improved. NASA's interstellar Internet includes all types of detectors in the network. The Department of Defense's converted communications system treats LEO reconnaissance and surveillance satellites as network users and network nodes. Europe's ISICOM also integrates ground observation and navigation satellites into space-based information transmission networks. Chinese SGIN will link the navigation Network and information acquisition networks. The future development will take the space-based integrated information network as the goal and adopt an integrated development strategy.

Space-based information transmission network, space-based information acquisition network, space-based navigation network and space-based information countermeasure network form a space-based integrated information network. The space-based integrated information network should also strengthen its comprehensive integration with land-based, sea-based and space-based information networks, establish operational information grids, and realize information sharing, seamless connection, interconnection and interoperability between various systems.

4. Summary

With the rapid development of aerospace technology, inter-satellite links, airborne processing, constellation networks, network protocols and other technologies have initially reached the level of
space applications. The construction of space-based information network has transitioned from theoretical research to the system construction stage, but there are limitations in spatial data technology and space energy. For a long time, the space-based information network will still be based on the ground network. The construction of space-based networks will be based on TDRS which naturally has inter-satellite transmission and control functions. The space-based information transmission network is a transmission system that does not generate information. In order to improve the timeliness of information and use network transmission efficiency, it is necessary to integrate space-based navigation systems and space-based information transmission systems to form a comprehensive space-based information network for information acquisition and space-time reference.

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