Analysis of Centralized Inter-satellite Link Network Coverage Based on STK and Matlab

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Abstract. Aiming at solving the problem of network coverage of GNSS system inter-satellite measurement and control link, the method of joint STK and Matlab is adopted. By using the interface provided by both parties, Matlab can directly control STK for task analysis, and obtain professional orbit data and star directly from STK. The distance information is processed and analyzed by Matlab. The preliminary analysis results of the link coverage of the centralized inter-satellite link network route show that the centralized network coverage is high and the on-board antenna resource utilization is high, but the load capacity of the satellite payload and the on-board data processing. The performance of the device puts high demands on it.

1. Introduction
At present, the world's major navigation systems are studying the "inter-satellite link" technology, and each has its own characteristics, such as the UHF band low-speed wide-beam inter-satellite link of the US GPS, and the S-band low-speed width of the Russian GLONASS navigation system. The inter-satellite link, China's Ka-band phased array mid-speed inter-satellite link, and the EU's Galileo navigation system are also stepping up their own inter-satellite link technology.

The existence of the inter-satellite link enables the GNSS to maintain the normal operation of the constellation and provide users with certain precision services without the support of the ground monitoring station [1-3]. The development of China’s Beidou satellite navigation system The start is relatively late, but some achievements have been made in the research of inter-satellite link technology, including the feasibility of analyzing link establishment for different constellation geometric characteristics, the impact of research on information transmission and the characteristics of different topologies. Comparative analysis of different routing algorithms and optimization of algorithms, etc. [4-7].

This paper mainly uses STK’s 3D display module VO and STK/Connect module [8] to connect STK with Matlab [9]. In this way, STK's powerful 3D display capability and professional computing power can be utilized, and Matlab can be used to complement the STK computing power, so that the inter-satellite link network can be analyzed more accurately and meticulously. The main research object is the walker-δ configuration constellation of 24/3/1. The coverage problem of inter-satellite link network is studied for the distributed and centralized network topology. The choice of inter-satellite link network routing Has a certain guiding significance.

2. Establish constellation and get data
The simulated walker constellation parameters N/P/F are set to 24/3/1, the orbital radius is 26561.8Km, the operating period is about 12h, and the orbital inclination is 55° [10]. This parameter is provided by
space-track.org. The data TLE is calculated, and the specific establishment method is referred to the literature [9]. Then, the required inter-satellite distance information report is designed in STK, and the data is extracted by Matlab instruction. The first satellite on the first track is taken as an example to control Matlab to obtain the distance information of all satellites on the second track:

```matlab
a=stkExec(conID, ['GetReport */Satellite/sat11 "dis2x" "1 Nov 2018 00:00:00.000" "1 Nov 2018 12:00:00.000" ',num2str(timestep)]);
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In this sentence, dis2x is the name of the report, which is set by the user. The calculation time range is from 0:00 to 12:00 on November 1, 2018, that is one constellation operation period, and timestep indicates the time interval for calculating the distance information, which is taken as 600s here. In this way, the total distance information of the eight satellites of sat11~sat18 to the satellites of the second and third orbits is obtained, and a total of 16 sets of data are obtained. Due to the symmetry of the walker constellation, it is no longer necessary to calculate the distance between the No. 2 and No. 3 orbiting satellites to the remaining satellites, and the distance information has been fully acquired.

After obtaining the distance information, the link will be designed based on characteristics or the requirements of the centralized network, and then study and solve its coverage, advantages and disadvantages.

### 3. Coverage of centralized inter-satellite link network

For a centralized network, some satellites with special locations can be selected to form a backbone network, and satellites at the backbone location can carry a number of antennas for inter-satellite measurement and control [11]. The advantage brought by this is that the inter-satellite network topology is relatively simple and distributed, and the complexity of the network topology changes is also greatly reduced. However, the problem is that the centralized processing of information puts high demands on the performance of the onboard processor and the ability of the satellite to carry the intersatellite measurement and control antenna.

With the minimum information transmission delay as the target, the distance information is used to select a few satellites on the No. 1 orbit that are relatively close to the satellites in the 2nd and 3rd orbits as the nodes to establish the network. Through simulation, it is found that within the first 600s of the satellite operation cycle, the 12th and 16th satellites can respectively see the total of six satellites from 24 to 26 and 21 to 22 and 28 in the shortest distance. Orbital satellite coverage reached 75%. At the same time, satellites No. 14 and No. 18 can be used to visualize all eight satellites from 31 to 34 and 35 to 38 with the shortest distance, with coverage of up to 100%. At this time, the 12th, 16th, 14th and 18th satellites need to be equipped with 3 or 4 inter-satellite monitoring and control antennas to complete the measurement and control tasks for other orbits. At the same time, the four satellites add two antennas at the same time to form the backbone network for information. Interaction to improve the accuracy of inter-satellite measurement and control. The specific network topology is shown in the figure:

![Figure 1 Initial time centralized link network topology (2D)](image-url)
The coverage of the second orbit, the third orbit, and the entire constellation network are analyzed, the results are as follows:

Figure 2 Initial time centralized link network topology (3D)

Figure 3 Link network coverage of orbit 2

Figure 4 Link network coverage of orbit 3

Figure 5 Link coverage of whole network
The centralized network no longer sets up the intersatellite links of the same orbits other than the backbone network. Therefore, regardless of the data hopping and the number difference of each satellite and update the link every 600 seconds. The coverage of inter-satellite link of the second and third tracks is up to 100%, and the lowest is 75%. The coverage of the inter-satellite link of the whole network is up to 83.3%, the lowest is 75%. Considering the difference in satellite number, to achieve 100% inter-satellite link coverage will take 280min, which is decided by the operation of the constellation.

For the construction of the backbone network, simulation analysis shows that only 4 satellites are needed, and the longest hold time is 60 min, the minimum hold time is 30 min, the link update frequency is moderate, and the measurement and control efficiency is high.

However, an analysis of the entire satellite operating period reveals that in order to complete the inter-satellite monitoring and control of the entire network, the eight satellites in the No. 1 orbit must be equipped with six inter-satellite measurement and control antennas to meet the needs of building an inter-satellite link network. It is the problem brought by the high network coverage of the centralized network. Does the satellite have enough carrying capacity to meet this demand to complete the inter-satellite link networking.

4. Conclusion

The GNSS constellation of the δ-walker configuration of 24/3/1 is simulated by combining Matlab and STK software, and the coverage of the centralized inter-satellite measurement and control link network in the whole network is analyzed based on the minimum information transmission delay. The centralized network is composed of a number of satellites that can cover the largest number of other satellites with minimum communication delay as the backbone network. The coverage is high and the link update frequency is moderate. The measurement and control links are not redundant. Maximize antenna resource utilization efficiency. It only challenges the payload carrying capacity of satellites in the backbone network and the performance of the on-board output processor.

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