Traffic Modelling and Simulation of Broadband LEO Satellite Communication System

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Abstract. Due to the rapid development of small satellite technology and the advantages of low earth orbit satellite (LEO) with low delay and low propagation loss as compared with the traditional geosynchronous orbit satellite (GEO), the broadband LEO constellation satellite communication system has gradually become one of the most important hot spots in the field of satellite communications. Many countries and satellite communication companies in the world are formulating the project of broadband satellite communication system. In view of the actual demand of China, in order to construct the broadband LEO constellation satellite communication system reasonably and effectively, and to research an efficient networking scheme, it is necessary to analyse traffic demand. This paper constructs the location-based traffic model and time-based traffic model. A method to simulate the traffic of broadband LEO constellation satellite communication system is proposed. And the traffic in one satellite and one orbit of the broadband LEO constellation satellite communication system are simulated respectively by using STK and MATLAB simulation software.

1. Introduction
The broadband LEO constellation satellite communication system has become a hot spot currently. Many countries and satellite communication companies in the world are building their own broadband satellite communication systems. OneWeb has launched the world's largest satellite Internet program, which will launch 648 satellites to build a global network of broadband communications. SpaceX plans to build an Internet constellation named STEAM which is composed of more than 4000 small LEO satellites to provide Internet access services worldwide. LeoSat plans to build a constellation composed of 140 satellites to provide broadband data access services to the whole world [1].

It is necessary for china to build the broadband LEO constellation satellite communication system [2, 3]. Considering the policy of China, it is impossible to build gateway station abroad to realize global personal communication [4]. Unlike the foreign satellite communication systems such as OneWeb, the broadband LEO constellation satellite communication system of China can't only use transparent forwarding mode. Because if the satellite only uses transparent forwarding mode, it is impossible to realize global communication and the utilization rate of space resources is very low. While if the satellite only uses on-board processing and on-board switching technology with inter-satellite link, the cost is high and the technology is complicated, what's more, the transmission
bottleneck of inter satellite link and feeder link will also restrict the transmission capacity of the system. So it is necessary to propose an efficient networking scheme combined with the traffic volume of the system.

Therefore, in order to build a broadband LEO constellation satellite communication system of our country reasonably and efficiently, we need to analyze the traffic volume of the system.

2. Influence factors

2.1. Analysis of Influence Factors

Since the development of economic and the population are different in different areas, the traffic volume of the satellite is constantly changing when the satellite passes through the population gathering area on the land. The demand of communication of the domestic users is greater than it of abroad so the satellite's traffic volume is extremely big when the satellite passes through the domestic area. There is nearly no traffic of the satellite when it passes through the ocean, desert, mountain, or polar region because the amount of users is so little in these areas. The traffic volume of the satellite is changing in a conspicuous and abrupt way when the satellite passes through different areas. It will reach a maximum level when the satellite passes through the domestic area. While it will reach a minimum level when the satellite passes through the ocean, desert, mountain and polar region.

Besides the location of the sub-satellite point, the traffic volume can be influenced by the local time of the sub-satellite point. In different periods, users communicate with each other in different utilization rate, depending on the local time of the satellite coverage area [5]. For example, the utilization rate of communication is higher in daytime than it in the deep of night. So we need to consider the influence of time to the traffic volume when analyzing the traffic of broadband LEO constellation satellite communication system.

2.2. Basic Ideas

There are two major factors that affect the traffic volume of broadband LEO constellation satellite communication system: one is geography and the other is time [6, 7].

Geographical factors. The land, the ocean, the mountains and the deserts on the earth are well distributed. In the land area, the economic development of various continents is different, and the demand for traffic is different. The traffic volume between domestic and foreign region is also different. In this way, when the satellite rotates around the earth periodically, the satellite will pass through different regions. As time goes on, the traffic source of the satellite beam will change greatly when the satellite beam swept across different regions.

Time factors: There is clear difference in the traffic volume at various periods of time in one day, due to different demand for communication at working time and rest time, which is related to the local time.

Therefore, in order to simulate the traffic volume of a satellite, we should build two basic models according to the two major factors that affect the traffic volume of broadband LEO constellation satellite communication system. One is the location-based traffic model and the other is time-based traffic model.

3. Two basic traffic models

3.1. Location-based Traffic Model

The location-based traffic model is based on the various geography. Considering that there is usually no people living in the north and south poles. The demand of traffic volume is extremely low there. And the satellite constellation of broadband LEO constellation satellite communication system have enough satellite over the north and south poles. We needn't to analyze the traffic of the satellite in the north and south poles. So the traffic volume is set to zero in the area of 70°-90°N and 70°-90°S. Then
the else area is divided into 56 * 72 grids at every 5 degrees longitude and every 2.5 degrees in latitude, with a total of 4032 grids, and the distribution of grid is shown in Figure 1.

![Figure 1. Distribution of grid.](image)

The density of traffic within each grid is calculated according to the number of population and level of economic development in the region [6, 7]. The traffic in various continents is calculated by assigning separate weighting factors according to the economic development of every continent: North America is 0.8, South America is 0.6, Africa is 0.4, Asia is 0.7, Europe is 0.8, and Oceania is 0.5. Some areas with small population distribution have low demand for traffic volume, with smaller weighting factors: the far sea zone is 0, the offshore zone is 0.1, and the desert zone is 0. The demand for traffic volume of domestic is much higher than that of the overseas, so the ratio of the domestic and overseas in traffic density is 10:1. Thus getting the system position. The location-based traffic model is shown in Figure 2.

![Figure 2. Location-based traffic model.](image)

3.2. Time-based Traffic Model

There is clear difference in the traffic volume at various periods of time in one day, due to different demand for communication at working time and rest time, which is related to the local time. In order to analyze the effect of time factors on the change of traffic volume, the relative change of traffic volume within one day is described, and a time weighting factor is proposed between 0 and 1. This model is the same for all parts of the world, as shown in Figure 3. The traffic in each grid will be multiplied by the corresponding time weighting factor.
It is very important to calculate the time weighting factor of each grid. Because of the high-speed operation of the satellite, the local time of the sub-satellite point changes very fast. So it is necessary to obtain the local time of the sub-satellite point. First the latitude and longitude of the sub-satellite point is obtained from the STK simulation software. Then getting the GMT time form STK. Last, converting the GMT time to the local time according to the latitude and longitude of the sub-satellite point as shown in Figure 4.

4. Traffic simulation

4.1. Ways of Simulation
The calculation of the volume of a single satellite can be carried out in the following way:
(1) Get the latitude and longitude of the sub-satellite point;
(2) Calculate the number of grid in the satellite's coverage area;
(3) As for each grid within the satellite coverage area:
   (a) Calculate the local time;
   (b) Determine the traffic volume in each grid;
   (c) Multiple the traffic volume in the grid with the time weighting factor.
(4) Add the traffic volume of all grids in the satellite coverage area together

4.2. Results of Simulation
With this method we can simulate the relative traffic of the satellite. The traffic of one satellite in 24 hours is shown in Figure 5.
Figure 5. Traffic of one satellite in 24 hours.

It can be clearly seen from the figure that the traffic volume of a satellite changes very fast with time, and it is outburst. The traffic volume is zero when the satellite passes through the ocean, desert, mountain, or polar region. And it peaks when the satellite passes through the domestic region.

5. Conclusion
This paper stresses the importance of researching the traffic of satellite with analyzing the current situation of broadband LEO constellation satellite communication system and the constraints of Chinese policy. It finds the main two factors that affect the traffic volume of satellite. And it constructs the location-based traffic model and time-based traffic model. The method to simulate the traffic volume of the broadband LEO constellation satellite communication system is putted forward. And the traffic of one satellite and one orbit plane is simulated.

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