Analysis of SINR according to Elevation Angle in Earth Fixed Beam

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***Abstract*—It is important to minimize handover for robust communication. In earth fixed beam, time that one satellite covers the same area must be considered. In order to consider the service time, the signal to interference plus noise ratio (SINR) should be taken into consideration. In this paper, we analyze the SINR of low earth orbit (LEO) satellite according to elevation angle. Simulation result shows that the average SINR increases when the elevation angle gets larger.**

***Index Terms*—Earth fixed beam, Elevation angle, SINR**

I. Introduction

To perform seamless connectivity in non-terrestrial network (NTN), handover is a challenge that needs to be addressed. In the fast mobility of low earth orbit (LEO) satellites, frequent handovers are unavoidable problems. Therefore, many studies related to LEO satellites are needed to reduce handovers. First of all, LEO communication method is divided into earth fixed beam and earth moving beam. According to [1], most of handover problems are simulated at earth moving beam. However it causes frequent handovers, because user equipments (UEs) try to handover when they see a better beam. Also, if many UEs find better beam at the same moment, they will handover to another beam simultaneously. They will also cause traffic congestion. In earth fixed beam, beams are fixed to a certain location on earth. The UE tries to communicate with the LEO satellite until it reaches a position where the elevation angle is less than the minimum elevation angle. So, the handover rate of the earth fixed beam is lower than earth moving beam, because the same satellite and beam can serve the specific area for much longer time. However, in the papers so far, there have been no papers specifically written on how to perform the service time of one satellite in the same area in the earth fixed beam scenario. To consider the service time, first of all, it should be calculated in consideration of the satellite communication environment such as signal to interference plus noise ratio (SINR). In this paper, we analyze the SINR according to the elevation angle of LEO.

II. System model

System model is shown in Fig. 1. Fig. 1(a) shows LEO and beams deployment. There are 1 LEO and 61 beams. The LEO is located at an altitude of 600 km and it moves at a speed of 7.56 km/s. At the terrestrial, each of the 19 beams in the middle has 10 randomly deployed UEs like Fig. 1(b). We consider D1 scenario, which is a fixed beam of the NTN reference scenario [2]. Frequency reuse factor (FRF) is option 1, which means all beams use the same frequency bandwidth. We consider S-band frequency band. According to [3], when FRF is option 1, two additional tiers of beams are need to be considered in the simulation surrounding the 19 beams layout. So, we deploy 3- and 4-tiers beams additionally in this system model. The type of terrestrial UEs is handheld.

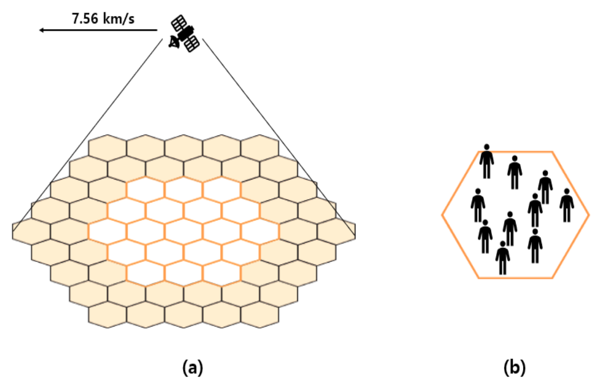

Fig. 1. System model (a) LEO and beams deployment, (b) UEs deployment.

We only consider large scale model between UEs and a LEO. The pathloss between them are as follows:

$$PL = FSPL(d, f_c) + SF + CL(\alpha, f_c), \tag{1}$$

where PL is path loss, $FSPL$ is free space path loss, SF is shadow fading loss represented by a random number generated by the normal distribution, i.e., $SF \sim N(0, \sigma_{SF}^2)$. CL is clutter loss, α is elevation angle, and f_c is carrier frequency in GHz. We consider suburban environment and the values of σ_{SF} and CL are given in Table I. The SINR is calculated as follows:

$$SINR = -10log_{10}(10^{-0.1SNR} + 10^{-0.1SIR}), \tag{2}$$

where SNR is signal-to-noise ratio in dB, and SIR is signal-to-interference ratio in dB. The SNR is calculated as follows:

$$SNR = EIRP - PL - k + G/T - 10log_{10}(BW/K_{FR}), \tag{3}$$

TABLE I
σ_{SF} AND CL ACCORDING TO ELEVATION ANGLE [3]

Elevation	LOS	NLOS	
	σ_{SF}(dB)	σ_{SF}(dB)	CL(dB)
10°	1.79	8.93	19.52
20°	1.14	9.08	18.17
30°	1.14	8.78	18.42
40°	0.92	10.25	18.28
50°	1.42	10.56	18.63
60°	1.56	10.74	17.68
70°	0.85	10.17	16.50
80°	0.72	11.52	16.30
90°	0.72	11.52	16.30

where $EIRP$ is equivalent isotropic radiated power in dBW, k is Boltzmann constant in dBW/K/Hz, G/T is the received antenna gain-to-thermal noise ratio in dB, BW is bandwidth in Hz, and K_{FR} is the bandwidth factor based on the selected frequency reuse scheme. The $EIRP$ is defined as follows:

$$EIRP = EIRP_{den} + RP_{sat} + 10log10(BW/K_{FR}), \quad (4)$$

where $EIRP_{den}$ is EIRP density in dBW/MHz. RP_{sat} is the normalised radiation pattern of antenna in dB. The SIR can be calculated as follows:

$$SIR = S - I, \quad (5)$$

where S is the signal strength in dB, and I is the interference strength in dB.

III. Performance Evaluation

In this paper, we use MATLAB to conduct the simulation. Elevation angle is set from 10° to 90° in 10° increments. The simulation time is set to 3000 seconds. We refer technical report (TR) 38.821 [2] for the antenna gain pattern of LEO satellite. EIRP density is set to 34 dBW/MHz and bandwidth is set to 30 MHz. Carrier frequency is set to 2 and 4 GHz. The diameter of beams in our simulation is set to 50 km. The environment of UEs is 100% outdoor environment. Other parameters are set based on the system level simulation (SLS) study case 9 of TR 38.821 [2].

Fig. 2 shows the result of SINR according to elevation angle with different f_c. When the f_c is set to 2 GHz and the elevation angle is 10°, it can be seen that the received SINR is around -17.5 dB. When the elevation angle is set to 90°, the average received SINR is around -1.2 dB. Overall, as the LEO reaches to higher elevation angle, the SINR of each cell increases. As the elevation angle increases, the influence of neighboring beam interference decreases. Also, according to equation (1), the PL decreases as the elevation angle increases. In addition, if the f_c increases, the corresponding SINR also increases. As f_c increases, the pathloss of each beam increases. As a result, the SNR received by each beam is reduced. In other words, interference of neighboring beams on the current cell is reduced, so that the SINR of the current cell is increased.

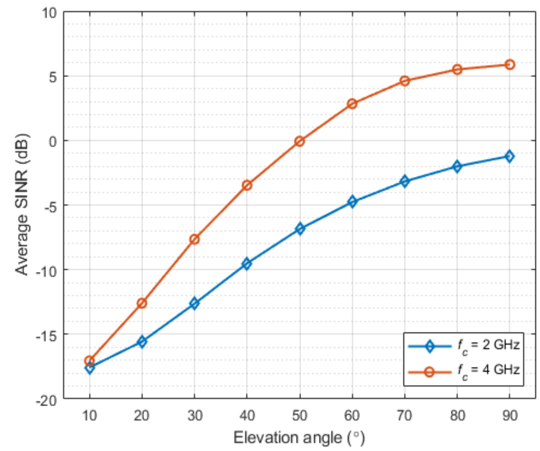

Fig. 2. SINR according to elevation angle.

According to [2] and [4], in LEO satellite networks, the beam size can be calculated from the angle of the beam edge with the gain reduced by 3 dB for maximum gain. However, in considering the beam size, only the antenna characteristics of the LEO satellite were considered. As stated in the specification of [5], the received SINR should be over the -8 dB. Then, when f_c is 2 GHz, an elevation angle over 50° is the serviceable signal quality. When f_c is 4 GHz, an elevation angle over 30° is serviceable. If the elevation angle is considered in determining the beam size, the beam size should be considered in various ways for each elevation angle in order to receive SINR as much as the signal strength specified in the standard.

IV. Conclusion

In this paper, we analyzed the SINR according to elevation angle in earth fixed beam. We confirmed that the SINR increases as the elevation angle increases. Mentioned by the specification of the current standard, the serviceable elevation angle is different according to the carrier frequency in our simulation. For smooth service in communication, it is necessary to modify the beam angle interval by elevation angle.

Acknowledgment

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