The Path Search Algorithm Utilizing Radio Propagation Characteristics of Ka-band GEO Satellite

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Abstract

Generally, the path search algorithm based on the shortest distance does not guarantee the provision of stable satellite services. The path search algorithm based on the received radio sensitivity has disadvantage such as the increase of its distance. This paper proposes a compound weight path search algorithm for satisfies the received radio sensitivity. It also prevents the increase of the distance and time. It searches the path according to the change of weight according to the distance and the received radio sensitivity-centered. The algorithm compares the time it takes to move the searched path. The proposed algorithm provides an effective and reliable satellite services.

Keywords: *Satellite Communications, Propagation, GEO satellite, Path search algorithm, Knife edge, Round edge*

1. Introduction

The satellite can be classified by its operation orbit such as LEO (Low Earth Orbit), MEO (Medium Earth Orbit), HEO (High Elliptical Orbit) and GEO (Geostationary Earth Orbit). The satellite communication utilizes the satellite on outer space. It offers a wide service area and lifts restriction of communication according to the disaster of the ground. A large number of receiver can use the same information at the same time. Because the satellite communication uses the super high frequency band, it is possible to offer a super high speed and high capacity communication [1].

The satellite communication signals the propagation loss at the communication link. The main causes of the propagation loss are free-space path loss and the atmospheric (the water vapor and the oxygen in atmospheric) absorption [2]. In addition, the propagation loss occurs due to an obstacle on the ground as the ground station is moving. Therefore, propagation environment characteristics analysis on the satellite communication is necessary in order to provide the stable satellite service [3].

In this paper, the received environments of the satellite radio are divided according to the movement of the ground station (*i.e.*, urban, suburban, and rural). This paper analyzes the characteristics of each environment. This also estimates the received radio sensitivity of the satellite. The estimation of the received radio sensitivity will offer a stable service in the satellite [4]. Real-time service in the GEO satellite communications is very important because the real-time services is required without interruption. For example, in the case of the DMB satellite services, if we do not receive the satellite radio, then the DMB satellite services is interrupted. However, by using the algorithm of this paper, we can provide the services without an interruption.

2. A Factor of the Satellite Communication Propagation Attenuation

The satellite communication propagation attenuation consists of various factors. The general equation of path loss between a satellite and receiver is as follows:

$$P_r(dBm) = P_t(dBm) + G_t(dB) + G_r(dB) - L_f(dB) - \alpha(dB) \quad (1)$$

where P_t is received power, G_t is transmission antenna gain, G_r is received antenna gain and L_f is the free space path loss. And α is propagation attenuation according to a received environment. It is the attenuation by the atmospheric absorption and the ground obstacles (knife edge, round edge and vegetation).

2.1 The free space path loss

A model of the free space path loss represents the propagation characteristics of the most basic radio path loss. It is as follows:

$$L_f[dB] = 20\log\left(\frac{4\pi d}{\lambda}\right)dB \quad (2)$$

where λ is the wavelength of the frequency, d is the distance between the receiver and the transmitter. In this formula, the value of free space path loss is decided according to distance [1].

2.2 The Attenuation by atmospheric absorption

The dry air and the water vapor in the atmosphere is caused by the absorption loss of radio waves. Therefore, the satellite communications should be considered for the absorption loss of radio waves by dry air and water vapor in the atmosphere. The loss of the absorption of radio waves by the atmosphere can be obtained as follows [5]:

$$A = \frac{A_o + A_w}{\sin\phi} dB \quad (3)$$

where, A_o is attenuation by dry air in atmosphere , A_w is attenuation by water vapor in atmosphere and Φ is the elevation angle. The elevation angle determined by the relative position of the satellite and receiving position. So, the elevation angle is the value between the satellite and the Earth's surface from the receiving position. The elevation angle can be obtained as follows:

$$E = \cos^{-1}\left(\frac{r}{R}\sin\phi\right) \tag{4}$$

w

where, R is distance between the satellite and the Earth's surface from the receiving position and r is distance between the satellite and the center of Earth.

In this paper, the elevation angle were applied 45˚, because the GEO satellite considered the Mukunghwa No.5 Koreasat and the receiving location was Seoul, Korea (E126 ˚, N37 ˚) [3].

2.3 The Attenuation by ground obstacles

In the satellite communications, the ground obstacles can be divided as knife edge, round edge and vegetation. This way, we can estimate to attenuation by the ground obstacles.

There are various estimated method of the attenuation by vegetation such as MAR model, ITU-R model, COST235 model, NZG model and Weissberger model. Among them is the MAR model which is possible to get a more detailed analysis by dividing the street trees and vegetation area. Because the vegetation attenuation by the satellite communications is occurrence, we use the MAR model in this paper. The MAR model with attenuation by vegetation can be estimated as follows [6]:

$$L_v = A_m\left(1-\exp\left\{\frac{-R_0 d}{A_m}\right\}\right)dB \tag{4}$$

where, d is the depth of vegetation, Am is the maximum attenuation and R0 is the rate of attenuation.

The top of the building showed the angular shape. Therefore, the knife edge model can be applied to diffract the attenuation by the building. The Diffraction attenuation due to the knife edges can be obtained as follows [6]:

$$L_{diff\_k} = 6.9 + 20\log\left(\sqrt{(v-0.1)^2+1}+v-0.1\right)dB \tag{5}$$

where, v is geometric coefficient as follows:

$$v = h\sqrt{\frac{2}{\lambda}\left(\frac{1}{d_1}+\frac{1}{d_2}\right)} \tag{6}$$

where λ is the wavelength, and h, d1 and d2 are the relative height and distance with the obstacle.

Since the top of the mountainous terrain is circular, the round edge model can be applied to diffract the attenuation by the mountainous terrain. The diffraction attenuation due to the rounded edge can be obtained as follows [7]:

$$L_{diff\_R} = J(v) + T(m,n) \tag{7}$$

in this case, J (v) is shown in Equation 5. But here, the geometric coefficient v of the equation is shown below:

$$v = 0.0316h\left[\frac{2(d_1+d_2)}{\lambda d_1 d_2}\right]^{1/2} \tag{8}$$

also, T(m,n) of equation 7 as follows:

$$T(m,n) = \begin{cases} 7.2m^{1/2} - (2-12.5n)m + 3.6^{3/2} - 0.8m^2 & mn \le 4 \\ -6 - 20\log(mn) + 7.2m^{1/2} - (2-17n)m + 3.6m^{3/2} - 0.8m^2 & mn > 4 \end{cases} \tag{9}$$

where, m and n are as follows:

$$m = R\left[\frac{(d_1+d_2)}{\lambda d_1 d_2}\right] / \left[\frac{\pi R}{\lambda}\right]^{1/3} / R \tag{10}$$

where, R is the radius of obstacle and h, d1 and d2 are the relative height and distance with the obstacle.

3. Simulation

In this paper, the path search algorithm uses the Dijkstra algorithm among existing short path search algorithm because the Dijkstra algorithm has a merit of high accuracy and easy embodiment. This section creates the virtual map for verification of the algorithm. The weight factors for the virtual map is classified such as distance (between the node and the node), the required time (between the node and the node) and the received radio sensitivity (The average between the node and the node).

The received radio sensitivity is chosen according to the environment such as urban, suburban and rural. The urban uses the knife edge diffraction attenuation by the building. In addition, the height and the density of the building in the urban is higher than the suburban. In the suburban, the height and density of the building is lower than the urban. In addition, the frequency of the emergence of the vegetation is higher than the urban. We can hardly see a knife edge diffraction attenuation in the rural environment. However, the round edge diffraction attenuation occur by mountain. The rural is the biggest environment of attenuation by the vegetation.

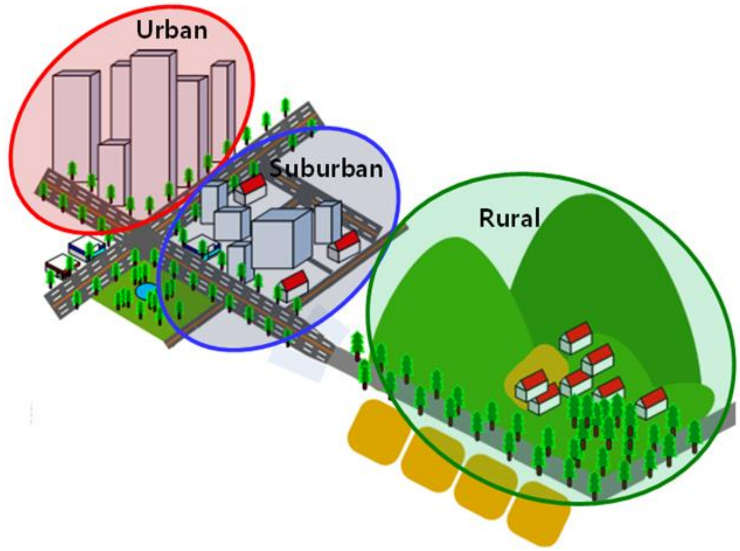

Figure 1. The simulation model for propagation sensitivity

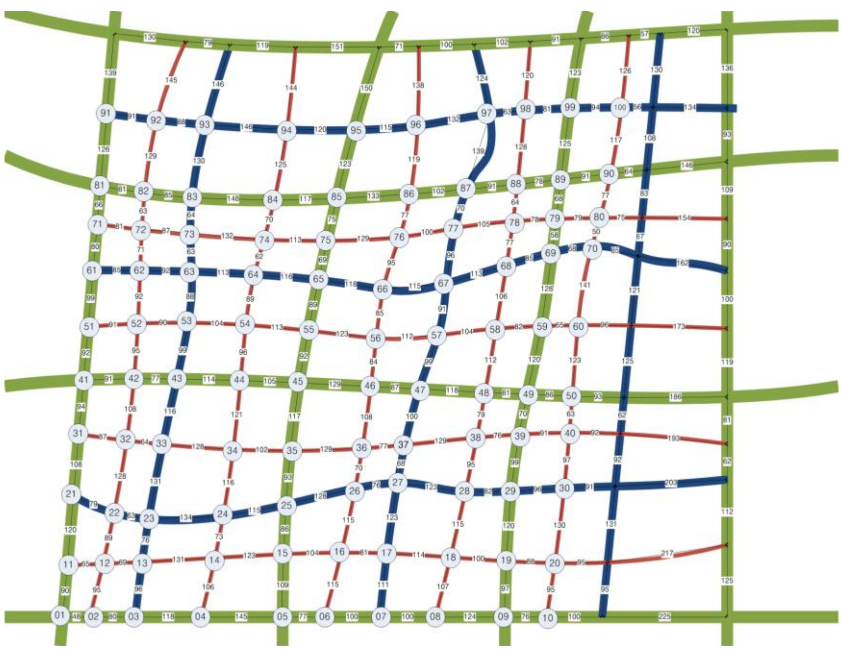

Figure 2. The simulation model for optimal path search

Table 1. Simulation setting of each environment

Received environment	Urban	Suburban	rural
The obstacle density(%)	*80*	*50*	*10*
The average height(m)	*60*	*30*	*20*
Height standard deviation(m)	*10*	*10*	*10*

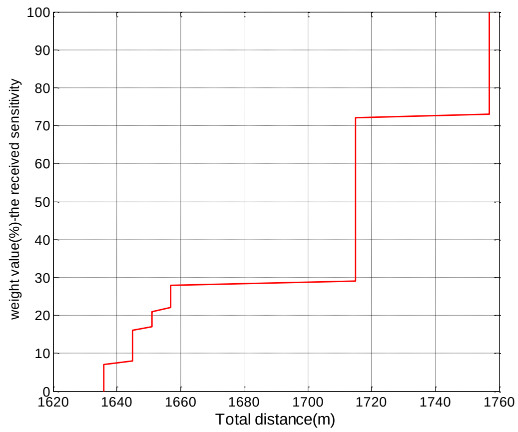

Figure 3. The distance with the weight value

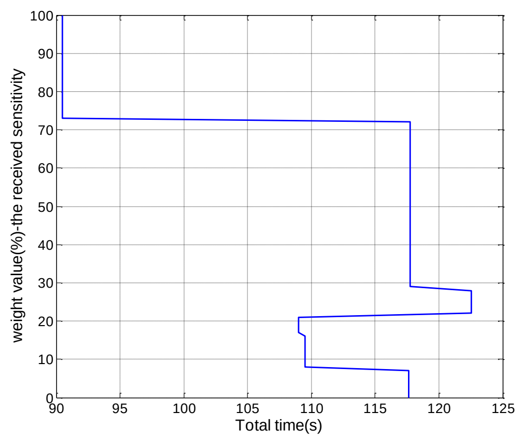

Figure 4. The total time with the weight value

A time take moving between the node and the node. Setting of the time depends on the width of the road such as Figure 2. The received radio sensitivity in each environment is set according to Table 1.

We found the path to node 100 from node 1 in Figure 2. The distance and the received sensitivity is the factor to determine the path. The distance and the received sensitivity are the factors determining the path. We tested how another path is found when the weight value of the received sensitivity is changed from 0 to 100%.is changed from 0 to 100%.is changed from 0 to 100%.

In Figure 3, the simulation results show the change of distance from the lowest (1.636 kilometers) to the highest (1.757 kilometers) according to the weight value of the received sensitivity. If we choose the path based mainly on the received sensitivity, then the disadvantage may occur such as the increase of the its distance. Also, In Figure 5 shows the change of the received radio sensitivity from the lowest (-171dB) to the highest (-154dB) according to the weight value of the received sensitivity. If the factor to determine the path is just the distance, it cannot guarantee a stable satellite service. Because, the path by the distance is show the lowest 1.636 kilometers. That time, the received radio sensitivity is show

-171dB. It is lowest the received radio sensitivity. The factor to determine the path is both the distance and the radio sensitivity. This guarantees a stable satellite service and satisfies a suitable distance. If the path will be determined only by the distance, it cannot guarantee a stable satellite service. Therefore, not only the distance, but also the radio sensitivity is determining the path in this paper for a stable satellite service and an appropriate distance. And it can show the required time to move the selected route as Figure 4. The advantages of this method are; first, it receives a radio sensitivity depending on the type of service. Second, . it has a short moving distance. And third, it saves time.

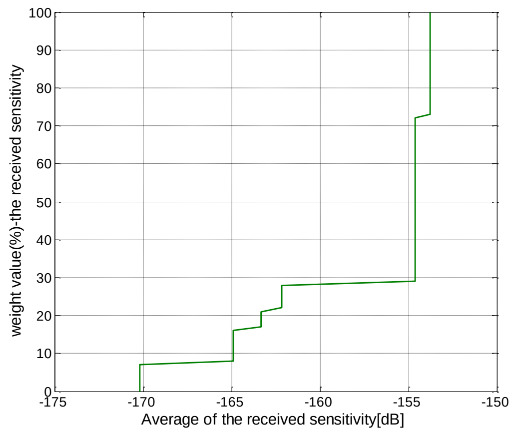

Figure 5. The received radio sensitivity with the weight value

4. Conclusion

In this paper, the path searched should be based on the weight by the distance and the received radio sensitivity-centered. It moves each searched path compared to the time. So, this paper can searched effective path. Generally, the path based on the shortest distance does not guarantee the provision of a stable satellite services. The path based on the received sensitivity causes an excessive increase of the distance and the time. The proposed algorithm in this paper satisfies the received radio sensitivity and prevents the increase of the distance and the time. It provides an effective and reliable satellite services.

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