Master's Thesis
석사 학위논문

Optimal resource allocation with fairness using opportunistic channel gains for LMS channels

Sungmin Ok(옥 성 민 玉 城 旼)

Department of Information and Communication Engineering
정보통신융합전공전공

DGIST

2015

Optimal resource allocation with fairness using opportunistic channel gains for LMS channels

Advisor : Professor Jihwan Choi
Co-Advisor : Professor Jaesung Hong

by

Sungmin Ok
Department of Information and Communication Engineering
DGIST

A thesis submitted to the faculty of DGIST in partial fulfillment of the requirements for the degree of Master of Science in the Department of ICE. The study was conducted in accordance with Code of Research Ethics[1].

11. 14. 2014

Approved by

Professor Ji Hwan Choi (Signature)
(Advisor)

Professor Jae Sung Hong (Signature)
(Co-Advisor)

1) Declaration of Ethical Conduct in Research: I, as a graduate student of DGIST, hereby declare that I have not committed any acts that may damage the credibility of my research. These include, but are not limited to: falsification, thesis written by someone else, distortion of research findings or plagiarism. I affirm that my thesis contains honest conclusions based on my own careful research under the guidance of my thesis advisor.

Optimal resource allocation with fairness using opportunistic channel gains for LMS channels

Sungmin Ok

Accepted in partial fulfillment of the requirements for the degree of Master of Science.

11. 14. 2014

Head of Committee____________(Signature)
Prof. Ji Hwan Choi
Committee Member____________(Signature)
Prof. Jae Sung Hong
Committee Member____________(Signature)
Prof. Ji Woong Choi

Contents

List of tables

List of figures

Nomenclature

i,j = user indices

N = number of users

$P_i(x)$ = probability that channel gain of user *i* is *x*

$N_i(x)$ = normalized channel gain when user *i*' s channel gain is *x*

$m_i(t)$ = mean value of user *i*' s channel gain at time *t*

t = time index

$\sigma_i(t)$ = variance of user *i*' s channel gain at time *t*

$P_{si}(x)$ = probability that user *i*' s channel gain is *x* and user *i* is selected to be allocated for resource

$g_i(t)$ = channel gain of user *i* at time *t*

P_A = average allocated power to users

EC_i = expected channel capacity of user i until time delay of current message

DS_i = the remaining data size of current message

$T_i(t)$ = expected transfer data size divided by the remaining message size of user *i* at time *t*

SF_i = scheduling factor of user *i*, ordering all users using specific values acquired from scheduling policy

RF_i = round robin factor of user *i*

F_J = jain' s fairness index

M_i = total transferred message data size of user *i*

K = number of multi beams

k = multi beam number index

E = Expected round robin factor; the number of allocatated number during a round

$N_{i_k}(t)$ = multi beam k signal transmitted to user i at time t

Abstract

We suggest a resource allocation algorithm for multibeam satellite systems over Land Mobile Satellite (LMS) channels. In the satellite system, effectiveness and fairness are conflicting objectives, which can be compromised by scheduling policies, e.g. Proportional fairness scheduling (PFS) and Max−Min fair scheduling. In this paper, we suggest a normalized opportunistic round robin (NOR) algorithm, which is different from opportunistic round robin scheduling (ORR) [7] in the way of allocation beams but the same at the amount of time resource allocated. The NOR algorithm allocates beams based on the normalized channel gains. By normalizing the channel gains, NOR exploits the opportunistic chance from the users channel history, and the differences of average gain among channels are compensated. The unfair resource allocation caused by channel gains is mitigated. As a result, the NOR shows better short−term fairness performance than the ORR, especially in the case of highly opposite channel gains. The motivation of this idea is briefly discussed using the probability theory, and supported by simulation results. The next feature of our consideration is fragmentation that is used to transfer large sized data. The DVB−RCS system is based on TCP/IP protocol, which divide a packet to several fragment and transmit. We suggest an entire packet transmitting prediction algorithm (PTP) to diminish the total packet loss amount caused by fragment loss due to insufficient channel capacity. This algorithm prevents the system from wasting the channel resource, which is used by the packet transmission with insufficient channel capacity. Therefore, users with higher probability of the successful transmission are allocated more bandwidth. The simulation results show that the PTP algorithm provides better performance with fragmentation.

I . INTRODUCTION

1.1 Characteristics of Land Mobile Channel

The terrestrial user experiences variety land mobile satellite (LMS) channel environment. The environment of satellite channel can be defined by the channel gain, the signal phase distortion and the propagation delay. The signal propagation delay between lands is much shorter than LMS channel, because of distance. In addition, as the kind of satellite altitude the propagation difference is large. Also transmit signal frequency is the main factor to be considered for spectrum interference and the LMS channel character. The weather is severe channel environment for transmit signal to be experience. The Doppler and shadowing effect are main factor of the signal power attenuation. The Doppler Effect is induced by the mobility of terrestrial user. The transferred signal is concentrated in specific frequency. However, the signal diverges and experiences the multiple path effect which is described in Fig. 1. Therefore, the relative speed of the land user is diverse and the distance of sender and receiver are variance. The relative speed between the sender and the receiver cause the frequency deviation, this is Doppler Effect, which represent the phenomenon of signal frequency changes, due to the relative speed between sender and receiver. In addition, each of multi path goes through shadowed obstacles, which cause signal attenuation. These effects are highly environment dependent and not easy to be considered precisely. To simulate the LMS channel, many mathematical approach using statistical method. Rician distribution model is well fit to describe the signal power when the line of sight signal power are concentrated and other scattered power is much lower, that is low shadowed signal. This is defined by using mean and Rician factor, which is the ration of the direct signal power and the scattered signal power. Otherwise, in the absence of a main signal power, and the scattered signal also experience shadowing, the Rayleigh distribution is adopted. In addition, there are many other functions to represent the character of LMS channels. The mobility of user requires more complicated representation about channel statistic function. As the user move, the channel environment also changes. To describe this character more specifically, the Markov model is used with statistic state transition. The simplest model is two state Markov model, which represented with good state and bad state. Good state means the channel is good to communicate, that is, losses is relatively low by various factors of weather, obstacles and channel state is consistent for relatively long period. The other state, which called "bad" state, is the channel of the high and fast variation and low channel gain by obstacles and weather condition. The channel gain means the effective channel power to communicate, as the value is high, the received signal power is also high. Lutz suggests this model at 1985. Using this model, we represent both users who are experiencing "bad" or "good" channel state. I reveal that the theoretical and recorded channel data, which are cited in here, are from Lutz paper [1].

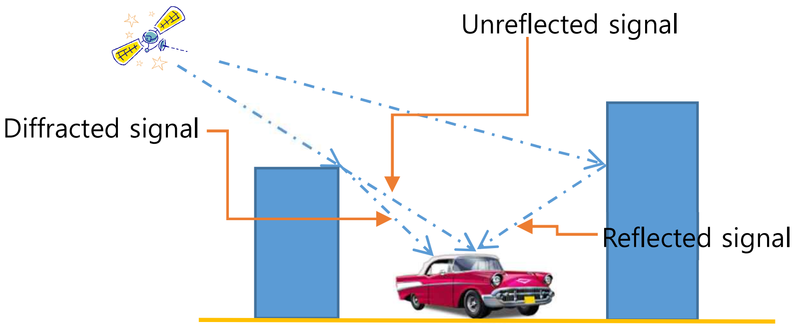


Figure 1 Multipath effect

Fig. 2(a), which is cited from Lutz model [1], shows the received signal power in an area with narrow streets of in the old city of Munich. This figure shows fast frequency fading by superimposed with low-frequency shadowing process. Channel gain has 15dB level difference between "good" and "bad" state. When the signal is line of sight and transmitted directly to receiver, the channel is corresponds to "good" state. Whereas, in the case that the signal is shadowed and reflected from the large numbers of surrounded obstacles, the channel gain is lower than "good" state and called "bad" state. As the mobile receiver is moving, the surroundings and the channel state are changing. From the recorded channel gain value cumulative probability, we can define the stochastic channel model using two-state-Markov model. This concept is described in Fig. 3.

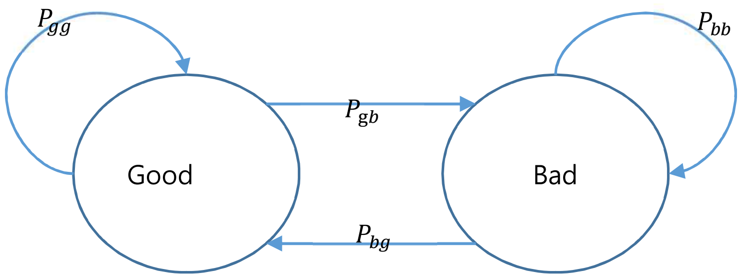
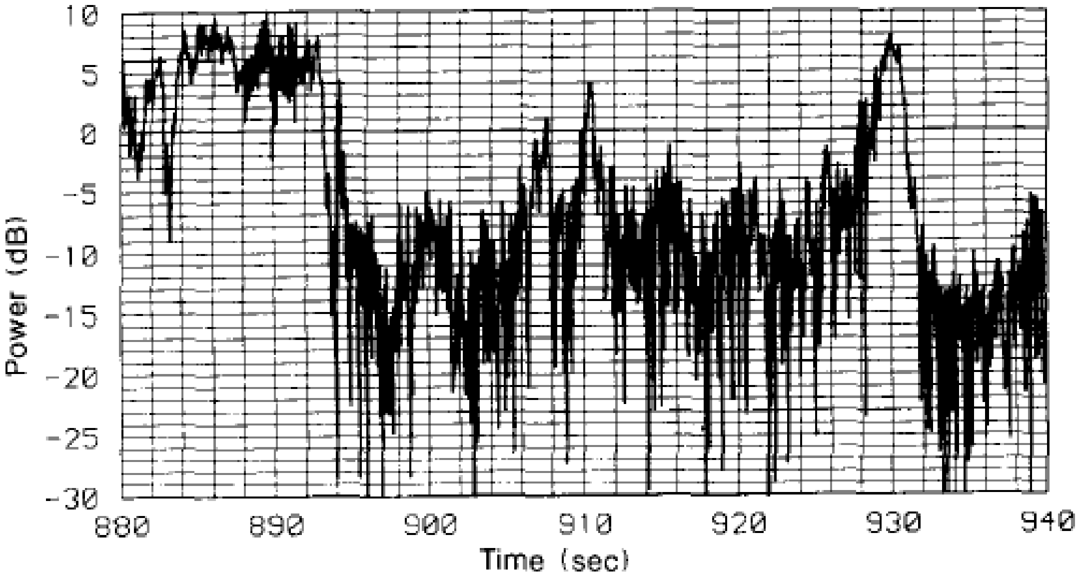
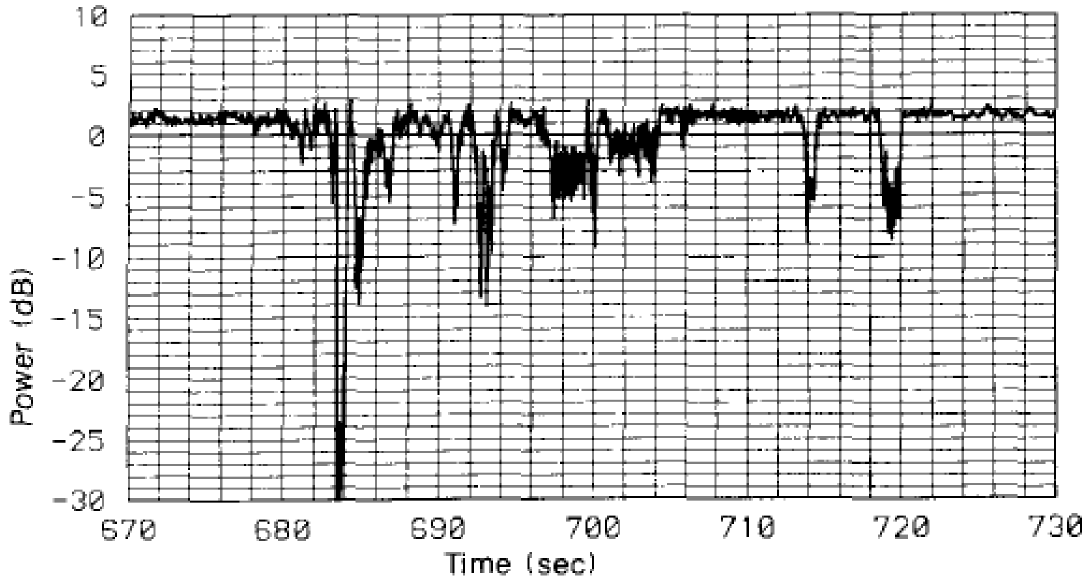


Figure. 3. Two state markov chain for LMS channel

Table. 1. represents the channel characteristic described by the Rician factor and the ratio of “good” and “bad” state. ‘A’ represents the ratio of “bad” state. This table is acquired from Lutz model [1]. When many obstacles surround the mobile terminal and the direct signal do not reach to mobile terminal, A is high. For example, city area and the road have higher ‘A’ value than opened highway. The case of satellite in 13° elevation angle, the mobile terminal is moving in highway. The ‘A’ value of the mobile satellite channel has 0.24, which means the channel state have “bad” state for 24% during the mobile terminal moving in highway. Besides, the channel state corresponds to “bad” state for 89% for city traveling. This result is quite reasonable, because the city have more screening buildings. “bad” state is more severe power loss than “good” state. In “bad” state, the main signal power is not exist and only reflected and deflected signal reaches to receiver’s terminal, therefor the channel power distribution follows the Rayleigh, which is less concentrated and highly random. Whereas, when the line of sight power directly reaches the mobile terminal, the channel is “good” state, which follows the Rician distribution.



(a)



(b)

Figure 1. Received Power level. 0 dB = mean received power. (a) City, antenna S6, v = 10 km/h, 24° satellite elevation. (b) Highway, antenna S6, v = 60 km/h, 24° satellite elevation

Parameters of the Analog and Digital Channel Model.[1] The Numerical Values of ϵ_g and ϵ_b Refer to DPSK Modulation with $E_{\text{link}}/N_0 = 10$ dB

Satellite Elevation	Environment	Antenna	A	$10\log c$	μ	σ	D_g	D_b	ϵ_g	ϵ_b
13°	Highway	C3	0.24	10.2 dB	− 8.9 dB	5.1 dB	90 m	29 m	$1.6 \cdot 10^{-3}$	0.23
	City	C3	0.89	3.9 dB	− 11.5 dB	2.0 dB	9 m	70 m	$1.4 \cdot 10^{-2}$	0.29
18°	City	C3	0.80	6.4 dB	− 11.8 dB	4.0 dB	8 m	32 m	$7.2 \cdot 10^{-3}$	0.29
	City	D5	0.80	5.5 dB	− 10.0 dB	3.7 dB	8 m	33 m	$9.5 \cdot 10^{-3}$	0.25
21°	New City	D5	0.57	10.6 dB	− 12.3 dB	5.0 dB	45 m	60 m	$1.3 \cdot 10^{-3}$	0.30
	Highway	D5	0.03	16.6 dB	− 7.1 dB	5.5 dB	524 m	15 m	$1.1 \cdot 10^{-4}$	0.19
	Highway	S6	0.03	18.1 dB	− 7.9 dB	4.8 dB	514 m	17 m	$7.6 \cdot 10^{-5}$	0.20
24°	Old City	C3	0.66	6.0 dB	− 10.8 dB	2.8 dB	27 m	52 m	$8.3 \cdot 10^{-3}$	0.27
	Old City	D5	0.78	9.3 dB	− 12.2 dB	4.4 dB	21 m	76 m	$2.3 \cdot 10^{-3}$	0.30
	Old City	S6	0.79	11.9 dB	− 12.9 dB	5.0 dB	24 m	88 m	$7.0 \cdot 10^{-4}$	0.32
	Highway	C3	0.25	11.9 dB	− 7.7 dB	6.0 dB	188 m	62 m	$6.8 \cdot 10^{-4}$	0.20
	Highway	S6	0.19	17.4 dB	− 8.1 dB	4.2 dB	700 m	160 m	$9.0 \cdot 10^{-5}$	0.21
34°	City	C3	0.58	6.0 dB	− 10.6 dB	2.6 dB	24 m	33 m	$8.3 \cdot 10^{-3}$	0.27
	City	M2	0.72	10.0 dB	− 11.9 dB	4.9 dB	21 m	55 m	$1.7 \cdot 10^{-3}$	0.29
	City	S6	0.60	9.5 dB	− 12.2 dB	2.0 dB	20 m	31 m	$2.1 \cdot 10^{-3}$	0.31
	Highway	C3	0.008	11.7 dB	− 8.8 dB	3.8 dB	1500 m	12 m	$7.6 \cdot 10^{-4}$	0.22
	Highway	S6	0.007	16.7 dB	− 13.4 dB	5.3 dB	1500 m	11 m	$1.1 \cdot 10^{-4}$	0.32
43°	City	C3	0.54	5.5 dB	− 13.6 dB	3.8 dB	42 m	49 m	$9.5 \cdot 10^{-3}$	0.34
	City	M2	0.65	11.0 dB	− 15.4 dB	5.4 dB	16 m	29 m	$1.1 \cdot 10^{-3}$	0.36
	City	S6	0.56	6.5 dB	− 15.6 dB	3.8 dB	51 m	65 m	$7.0 \cdot 10^{-3}$	0.38
	Highway	C3	0.002	14.8 dB	− 12.0 dB	2.9 dB	8300 m	17 m	$2.0 \cdot 10^{-4}$	0.30
	Highway	M2	0.002	17.3 dB	− 13.8 dB	2.0 dB	8300 m	17 m	$9.2 \cdot 10^{-4}$	0.35

Table 2 Channel Characteristics of Land Mobile Satellite, cited from [1]

To calculate the transition matric of Fig. 2. The time interval and the speed of mobile terminal should be considered. For example, if the first low data case is assumed and the mobile terminal is moving in 90km/h speed. The mobile terminal experience "good" state for $x = \frac{90m}{\frac{90km}{h}} = 3{,}600\text{msec}$ in average. And the "bad" state is sustained for $x = \frac{29m}{\frac{90km}{h}} = 1{,}160\text{msec}$. The state transition occurs in 10msec interval. Than the average "good" state consistency is 36 long and "bad" state sustain for 11.6 long (Transition occur in every 0.1sec). After a few mathematical steps, it is calculated that P_{gg} is 36/37 and P_{bb} is 11.6/12.6. $P_{gb} = 1 - P_{gg} = \frac{1}{37}, P_{bg} = 1 - P_{bb} = 1/12.6$. Channel capacity described using Shannon channel capacity theory (1).

$$C\left(\frac{bits}{Hz}\right) = log_2\left(1 + \frac{S}{N}\right) \tag{1}$$

S/N is the signal to noise power ration in linear scale. We substitutes this factor as P(power)*g(channel gain). 'g' means the channel gain with average value 1. If the value is 1, the received signal power is average. This approach is quite useful, because this expression do not need real S/N power for estimating the channel capacity, but the average received power is required (2).

$$C = b\ g_2(1 + P * g) \quad (2)$$

The Matlab produce the random channel gain using "Ricianchan" function. Which function requires two parameters (maximum Doppler shift, k−facto). Doppler shift is the frequency shift from the relative velocity. Maximum Doppler shift is calculated as follow.

$$\Delta f = \frac{v_{r,s}}{c} * f_0 \quad (3)$$

As the relative velocity and the frequency are higher, the maximum frequency shift is higher. Therefore, if the transmitter and the receiver are stationary, this factor would not need to be considered. The resent communication system consider the mobile terminal, and the frequency of down link is high (Ku band: 10.95GHz~). Therefore, the system consider Doppler shift. In the city, we assume the maximum speed of mobile station is 30Km/h, and use central frequency with 10.95 GHz. $\Delta f = 30 * \frac{1000}{3600}\left(\frac{m}{s}\right) * 11 * 10^9 * \frac{1}{3*10^8}\left(\frac{m}{s}\right) \cong 306$. The other parameter of Rician channel is the rician factor. Which is the ratio of line of sight and the scattered multipath signal. As the rician factor value is higher, the signal power is concentrated to line of sight signal power. The rician factor of highway at 13° elevation angle is ≈10dB. To produce "bad" state channel, use Rayleigh process, which require the maximum Doppler shift, we assume this parameter value is same as Rician's.

1.2 The Multi−Beam antenna satellite

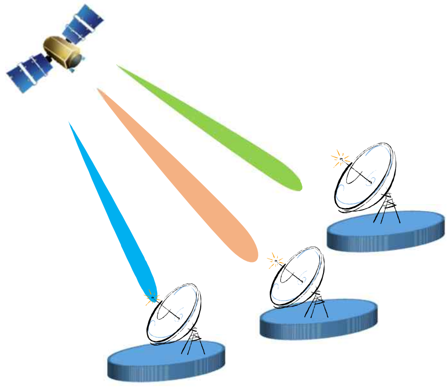


Figure 4 Multi beam array antenna

The multi−beam array antenna can generate multiple spot beam of which use different frequency, direction and power. This feature is able to increase the efficiency of satellite communication capacity [2]. The coverages of these spot beams are narrow, so diminishes the interference between terrestrial terminal users, using the same frequencies in different cells. The multiple beams can cycle very rapidly by beam allocation scheduling. In this paper, we suggest resource allocation scheduling based on beams, the power of beams and transmission time.

1.3 Fragmentation

Communication systems have various data rate in the condition of system and the channel state. The data have various size. Some data rate cannot support continuous data transmission, due to not enough data rate and limited channel occupation time. The system transfers the data in the shape of packets. Packets include extra information for regenerate the original data, and the fragmented data. As the data rate and diagram of the system, they have different packet size limitation. The cost of packetizing is not negligible, therefore fewer packet number is preferred to send the amount of data. The primitive satellite communication only supports the low data rate, voice, mail, etc. As the hardware and antenna technology has developed, the satellite implements the wide and higher frequency bands. This advanced satellite communication technology enables the various data service and the satellite communication service includes the IP layer communication system, which support packetizing data. These days, many kinds of application data, picture, video clip, and various IP packets, are transferred through the satellite communication. These multimedia data traffic require the real−time transmission. To aid this versatile service, it is necessary to send packet with time limitation [3].

Ⅱ. Section 1: Effective Allocation Algorithm for Fragmentation

2.1 Approaches to intact packet transfer

In this paper, we concentrate to increase the total packet throughput with limited time bound. It is assumed that the packet data, which is partially transmitted, are not counted as a total throughput. This approach is quite realistic in network layer. IP messages are fragmented and transmitted by underlying layer. The physical layer has limitation of data rate. Therefore, maximum transmission unit (MTU) limits the maximum size of datagram. The regular Ethernet frame limits the 1,500byte for a datagram. The packet is fragmented and transmitted in physical layer. Even though the fragment transmission has finished in physical

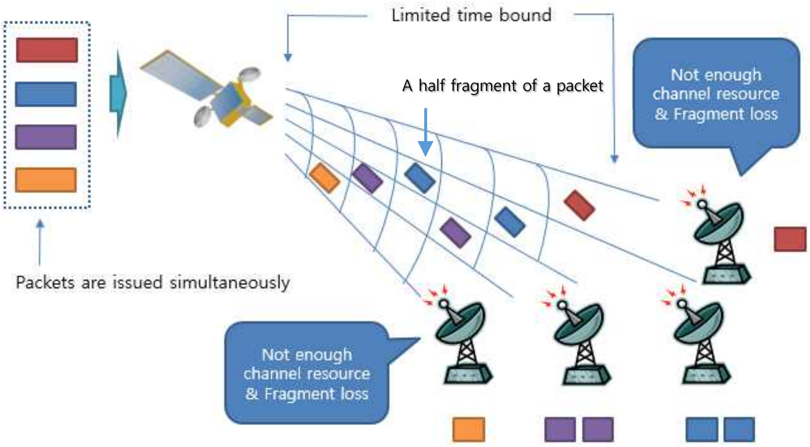


Figure 5 Fragmented packet transfer

layer, the application layer has not received whole packet to proceed service. The land mobile satellite channel is unpredictable and unstable. Therefore, there is possibility that the packet transmission is not completed. Single fragment loss causes the entire message to be useless [4]. The imperfectly transmitted packet size is waste of channel and time resource. To mitigate this inefficient resource allocation, the channel estimation algorithm and developed scheduling algorithm are required. It is suggested that the scheduling algorithm with channel prediction to prevent the imperfect packet transmission. This algorithm estimate channel status based on channel gain history. Then, the system considers the packet transmission to the terminal that have enough channel capacity to finish the packet transmission in limited time bound in figure 3. The land mobile satellite channel is usually unstable and unpredictable. The short channel coherence time is the obstacle of large packet transmission. Because, the relatively long transmission time has higher chance to make error by uncertain radio channel state. The packet data issued by application layer, are fragmented to smaller sized data transmission, in many communication systems. The receiver reassembles all fragments and reconstructs an original packet. A fragment loss causes the entire packet to be useless and a fragmentation and reassembly process should satisfy the maximum delay constraint [4], [5]. For successful message transmission, each of the fragments should arrive in time bound from the issued time. The instability of LMS channel cannot guarantee this requirement. The scheduling algorithm should consider this issue. The performance of the algorithm, which is intended to solve this issue, should be evaluated by the amount of completely transferred packets, which fulfill this criterion about time and intact transmission not by the physical layer throughput.

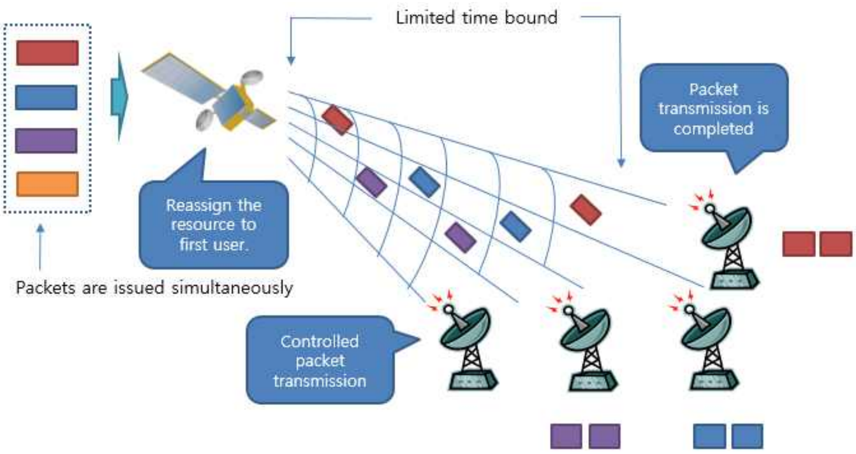


Figure 6 Intact packet transfer

2.2 Key Concept of PTP algorithm

The packet transmitting prediction (PTP) algorithm is for reducing fragment loss. The uncertainty of LMS channel gain and the discontinuity of resource allocation can cause imperfect packet transmission. This difficulty decreases the ratio of successfully transferred data to total throughput. The prediction, that the packet is transferred successfully or not, can help to classify the meaningless fragment transferring or the possible transferring, and prevent from transmitting a meaningless fragments of the message which is sent by bad channel capacity, which is not enough to send whole message fragments. The saved resources by this restrain can be allocated to other users, such that the resource utilization efficiency will be improved. The main concept of the prediction algorithm is comparing the expected data size to be transferred to the limited time and remainder size of the message. If the expected size is larger than the remainder, the satellite will allocate resource to the user, which requested message. If the expected size is larger than the remainder, the satellite will allocate resource to the user, which requested message. When the system expects the data size to be transferred, it predicts the future channel capacity by Shannon channel capacity. The channel gain and the power are assumed that the average channel gain and the equally allocated power to all beams and the bandwidth are equal to all beams for simplicity. We assume that each of the users demand packet transfer randomly by the equal probability. The size of the packets and the time bounds are constant to reduce the simulation complexity. The channel capacity is assumed that it is not enough to send the entire packet at one time slot, thus a message is divided into various sized fragments. The fragments size depends on the channel capacity and the power allocated to the user. If the packet is not transferred perfectly within the limit time, it will not be counted as the practical throughput. The PTP algorithm is used by combining other resource allocation algorithms, because this is limited method to a certain point, that the channel capacity is not enough, but for general policy to other situation. We analyze the PTP algorithm by combining with Max CNR Scheduling, Opportunistic Round Robin scheduling and Normalized Opportunistic Round Robin that is suggested in this paper. In general, the PTP algorithm helps them to increase the practical throughput performance.

Ⅲ. Section 2: Fairness Allocation Algorithm with Normalized Gain

3.1 The scheduling algorithms

The narrow spot beam antenna increases the total capacity of satellite communication system and has more complexity in scheduling policy by multiple access using multiple beams and time slot based allocation. The resource allocation policy covers the optimization of multiple beams, the power of beams in every time slot. The priority of policies diverse the optimal point of scheduling algorithms. There are two major point of resource allocation. Which are the maximized total throughput and the fairness oriented scheduling. The first one concentrates the efficiency of beam and power resource. This algorithm purses the ratio of data rate per consumed power of satellite. The higher carrier to noise ratio (CNR) is the condition of this algorithm, because the data rate is optimal in maximized CNR scheduling. In the other hands, the fairness oriented scheduling concentrates on the fairness between cells. The points of fairness are various, which are the time fairness, throughput fairness etc. Round Robin is well-known fairness scheduling policy. This algorithm cycle the beam allocation to static priority and equal time resource. However, this is may not fair in data throughput. Because the channel gain is various in different users, the equal time resource is not guarantee the equal data capacity that is decreases as the lower channel gain. Therefore, round robin is only give same time chance to all users but not same data rate. As the satellite traffic type is various, the application requires the several conditions on satellite packet transmission. For example, minimum time interval in retransmission and the minimum data rate to support the service. These requirements are more and stricter to satellite system to reliable service. Therefore, the quality of service is necessary and the fairness is inevitable attribute to assure the quality of service to all of service users. Round Robin scheduling can allocate the same time slot to all of users in every cycle, which can guarantee the minimum time interval of resource allocation. As a result, the frequent resource allocation aspect of Round Robin policy supports the real-time services, for example, data streaming, VoIP, and real time SNS services, even in bad channel condition. The shortage of this Round Robin policy is the fixed priority of resource allocation, which can be improved by utilizing the channel information of all users, which is available to satellite system. The best moment to send data signal to terrestrial user is unpredictable because the channel condition changes continuously. Opportunistic Round Robin policy (ORR) suggests the instinctive solution about this limitation. This keeps the cyclic allocation to all users and allows the flexible order of current user selection by using channel information. The user in best channel gain is selected as the signal receiver in every scheduling time. The opportunistic of ORR means the opportunistic channel information is adopted to improve the efficiency.

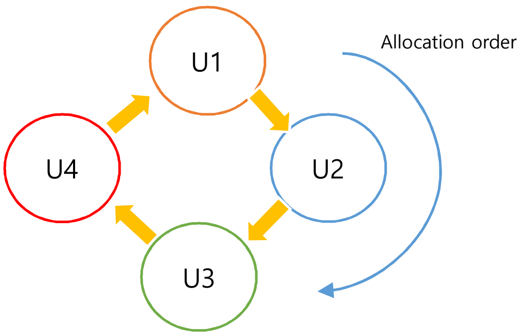


Figure 7 Fixed allocation order of RR

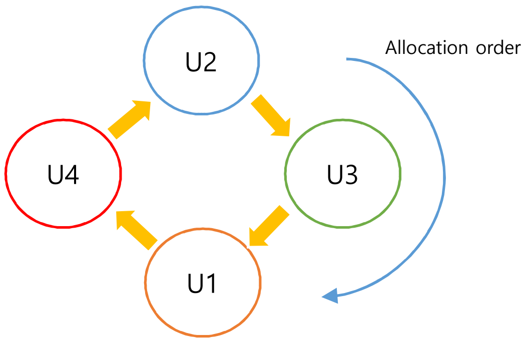


Figure 8 Flexible allocation order of ORR

3.2.1 The normalized channel gain and normalized opportunistic round robin scheduling

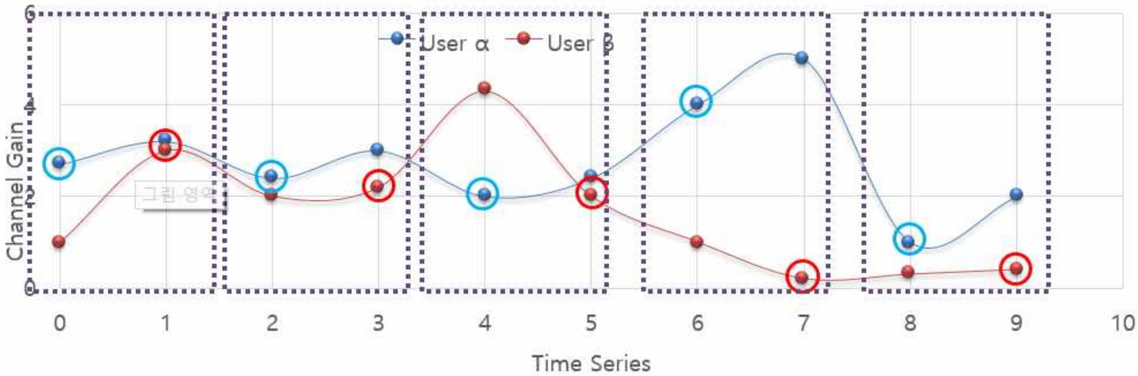


Figure 9 RR scheduling

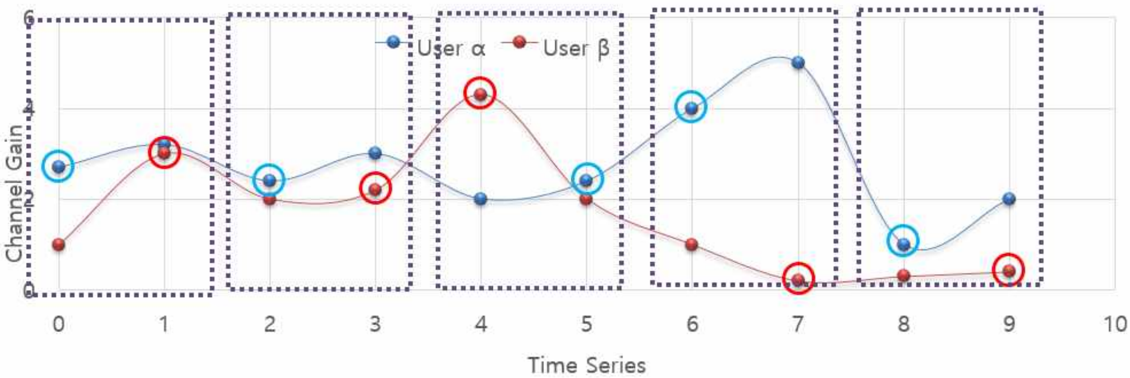


Figure 10 ORR scheduling

The terrestrial user can experience the channel variance due to environments of signal transmission and communication system. And the channel condition of each users are different, which are the obstacles in channel propagation path, the weather impairments, the path loss variation in non−geostationary satellite systems, frequency dependence, receiver antenna characteristics, etc. The channel gain of each user is variance but the channel condition in consist is also exist, for example, the receive antenna, the mobility of user terminal, weather conditions, the path loss, etc. These factors are static enough to be analyzed and utilized by satellite system. When the system considers channel condition to schedule the resource allocation order, these factors should be considered for the more effective communication. Below graph is the simple example of the resource allocation in case that two users and one spot beam are. The allocation order is fixed, user α is served first and user β is second. Two users are allocated in one time in every round that is pointed by dot line. Besides, the case of ORR scheduling, the order is flexible. At the time four and five, the sequence is different. The two circles exist in higher channel gain timing to both users. As, the higher channel gains are implemented, data rate has increased. This scheduling policy is possible based on the current channel gain information. Then, what if we have corrected the time channel information for enough time and estimated the average channel capacity during current coherence period, the channel value would be estimated more profoundly. Each user terminal has different channel gain values because of the different channel environments. Therefore, the current channel gain has the different rareness for each user terminal. A channel has the highest gain point and lowest gain point within short−term. If all of users are allocated beam at its highest channel gain, the throughput will be maximized under equally allocated time slot condition. However, this assumption is unrealistic. Because the channel gain is unpredictable, the system can judge the current channel gain is the best choice for the current short period. The compromising method is using normalized channel gain. The meaning of 'normalizing' is come from the normalizing the various probability distribution with the mean and the variance. The channel gain has consistency for coherence time, which is longer than the short−term period. Therefore, the static value of channel gain mean and variance for coherence period is proper.

We suggest the resource allocation based on the rareness of user's channel gain.

$$N_i(x) = \frac{x - m_i(t)}{\sigma_i(t)}, \{t | t_0 < t < t_M\} \tag{1}$$

$N_i(x)$ is the normalized channel gain of user i. m_i and σ_i are the mean and variance respectively during coherence period, which is from t_0 to t_M, when the channel has the constant mean and variance. These mean value and variance value are calculated by the record of the channel gain by analyzing the channel record. To limit our consideration into scheduling algorithm, we assume that the channel mean and variance are known. In addition, as the other resource allocation algorithms, which are above, the extended window factor of round robin is adopted to restrict the number of the allocated time slots for each user [5]. This opportunistic resource allocation approaches are considered in other papers, which is proportional fair scheduling [8]. The main difference of NOR with proportional fair scheduling is the basic information of considering the past channel gains. The NOR adopts the coherence channel concept to ordering the users but the proportional fair utilized the sum of the total past capacity of the user [8].

The extended window factor is the number of chances for allocation and it is equally distributed to users. This approach is justified in short-term fairness [3] and in increasing effectiveness of fairness scheduling [6]. Having the same number of chances, the algorithm should choose proper timing for allocation, based on the channel gain variation. A channel has the highest gain point and lowest gain point within short-term. If all of users are allocated beam at its highest channel gain, the throughput will be maximized under equally allocated time slot condition. However, this assumption is unrealistic. Because the channel gain is unpredictable, the system can judge the current channel gain is the best choice for the current short period. The compromising method is using normalized channel gain. This idea has supported by probabilistic approach.

$$P_{s\,\alpha}(x) = P_{\alpha}(x) \int_{y=0}^{x>y} P_{\beta}(y)dy \tag{4}$$

This equation is the probability of resource allocation. There are two user α and β. At some point, only one user is selected as receiver. This system selects the user who has higher channel gain. The system adopts round robin policy, which allocate the same time resource to all of users demanding the packet transfer. Therefore, the system should choose better timing to allocate. Eq. 1 represents the probability of the selecting α between two users α, β. $P_{\alpha}(x)$is the probability that the channel gain of user α is x. $\int_{y=0}^{x>y} P_{\beta}(y)dy$ is the probability that the channel gain of user β is y and y is less than x, that the channel gain of user α is higher than user β' s.

$$P_{s\,\alpha}(x) = P_{\alpha}(x) \int_{y=0}^{N_{\alpha}(x)>N_{\beta}(y)} P_{\beta}(y)dy \tag{5}$$

Eq. 3 is different from Eq. 2 in $\int_{y=0}^{N_\alpha(x)>N_\beta(y)} P_\beta(y)dy$. The range of integral is from 0 to $N_\alpha(x)$, but is from 0 to x. If the mean value of x is higher than y, the probability of x>y is higher than $N_\alpha(x) > N_\beta(x)$. Therefore, user α is easier to be selected than user β. This tendency cause unfairness between user α and β. Because user β is have lower probability to be selected prior to user α. Normalizing based on channel gain mean and variance release this unfairness problem. Below graph shows the simple example of two difference scheduling policy. In Fig. 9, Yellow circle indicate the user selection based on normalized gain, and blue circle indicate the user selection based on channel gain. At time 9 and 10, both user α and β are selected higher channel gain by normalized gain than by channel gain. This consequence is revealed by more detailed simulation of two users' case in Fig. 11. We assume that two channel of user α, β have Gaussian distribution with different means of channel gains. The average channel gain of user α is 4 and user β is 8 with σ = 1. In Fig. 11, the green lines represents the distribution of channel gains, user α's and user β's. Blue and red represent the distribution of selected channel gains by unnormalized case and normalized case respectively. The average mean of blue line is lower than red line, and the case of red is same. This means that the selecting algorithm based on normalized channel gain helps the

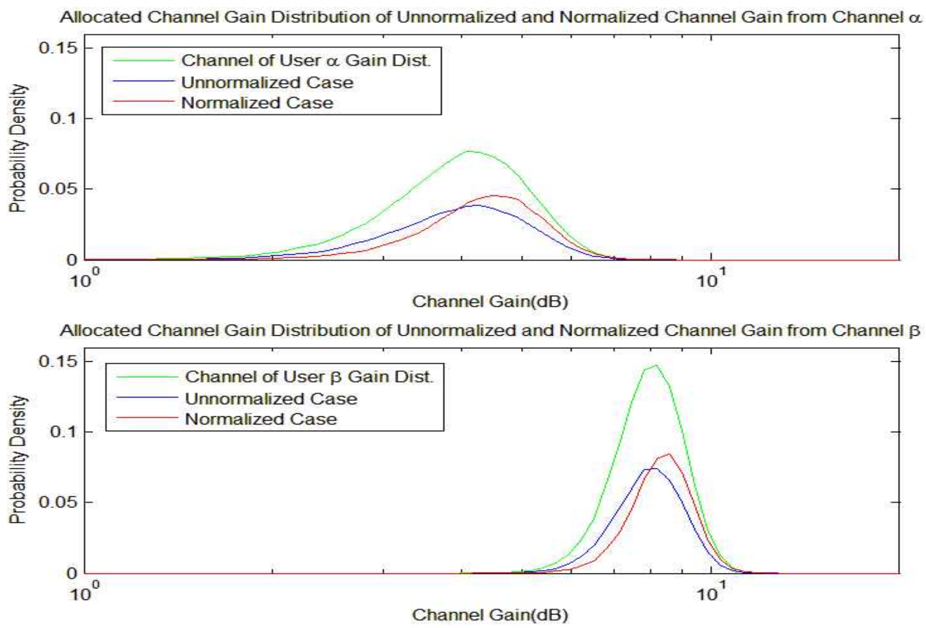


Figure 11 Simulation on channel gain distribution by ORR and NOR

higher channel gain to be selected for both users. Fig. 12 is the other simulation result of realistic channel gain.

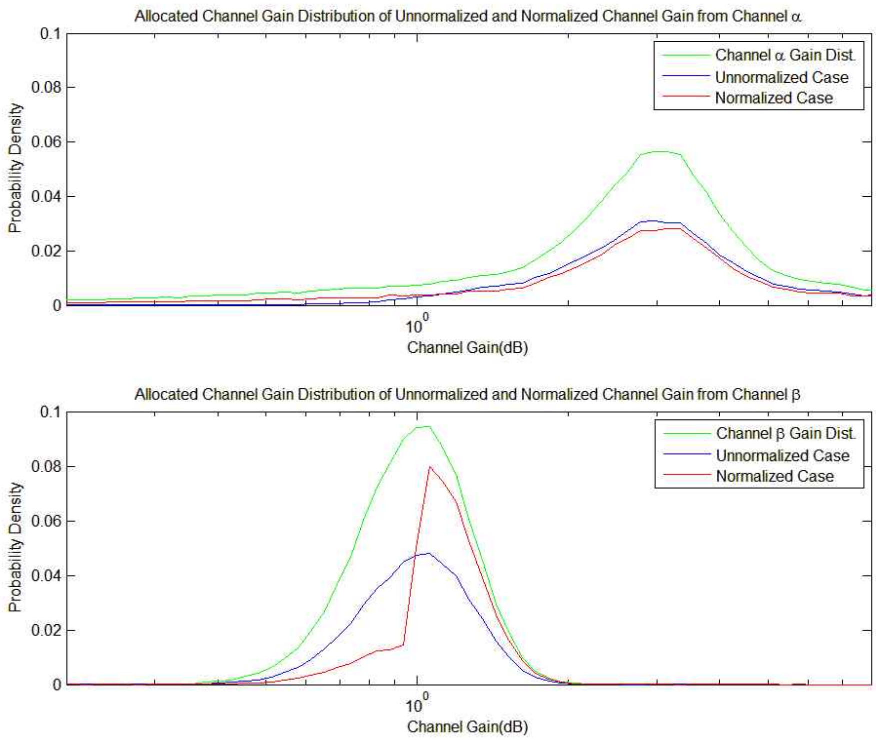


Figure 12 Simulation on channel gain distribution by ORR and NOR

	User α	User β	Total data rate(fairness)
The average channel gain by ORR	1.2005	0.5108	
The average channel gain by NOR	1.0718	0.5721	
The average data rate by ORR	2.7089	2.1877	4.8966(0.9902)
The average data rate by NOR	2.5336	2.2741	4.8077(0.9971)

Table 2 Fairness and Throughput of ORR and NOR

Average signal to noise ration of each user are 10dB of user α and 5dB of user β approximately. Total capacity is decrease by user NOR but, the capacity of user β has increased. The fairness has increased. Furthermore, total capacity decreasing of NOR scheduling is relieved, as the number of user is increase.

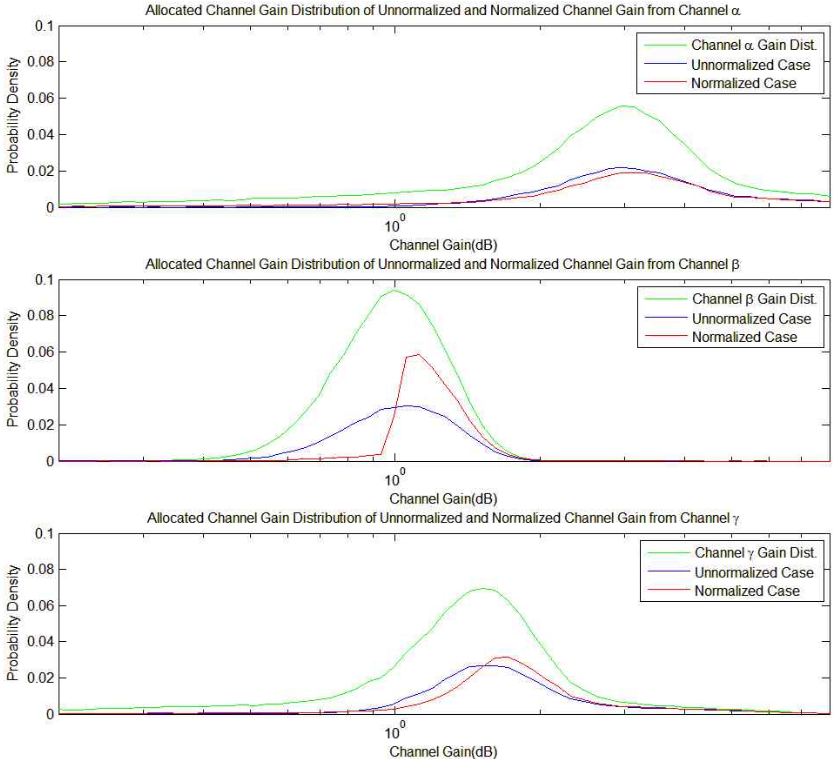


Figure 13 Simulation on channel gain distribution for three users by ORR and NOR

	User α	User β	User γ	Total data rate(fairness)
The average channel gain by ORR	1.2241	0.3473	0.6240	
The average channel gain by NOR	1.2062	0.3983	0.6435	
The average data rate by ORR	2.3973	1.8442	2.0808	6.3223(0.9886)
The average data rate by NOR	2.3284	1.9182	2.0851	6.3316(0.9937)

Table 3 Fairness and Throughput of three users' case

There are three user and one beam in fig. 13. The average channel gains are that α is 15dB, β is 5dB and γ is 10dB. Total data rate has increased than the case of two users. As the number of user is increase, the total capacity is also increase, and fairness increased than the case of ORR case.

3.2.2 Normalized Opportunistic Round Robin Algorithm

A Real-time service such as satellite phone, video streaming, and text messages requires sustainable connection. Data should be exchanged frequently, using small size of data. Short−term fairness is essential requirement for these kind of real−time applications [6]. Short−term fairness guarantees frequent data transmission to sustain real−time services. The Round Robin scheduling algorithms is good application for short−term fairness. This algorithm forces for all of the users to be allocated same time slots within short period enough to satisfy the quality of services (QoS). The normalized opportunistic round robin is similar with [6], but users are selected by normalized gain at each time slot. We assume that the mean and variance of user channel gains are known for computing normalized channel gain. The following Optimization problem implicates maximizing normalize the opportunistic round robin factor with limited time for each extended round.

$$arg \max_i \sum_{t=1}^{N*E} \sum_{k=1}^{K} N_{i_k}(t)$$

$$\text{Subject to } \sum_{t=1}^{N*E} S_i(t) = E, for\ all\ i \qquad (6)$$

$$S_i(t) = 1, if\ the\ user\ i\ is\ allocated\ the\ resource\ at\ time\ t, \text{else } S_i(t) = 0$$

3.2.3The Normalized Round Robin algorithm with PTP

Until now, we have discussed NOR and PTP algorithms, and pointed out the key concepts of these. We now focus on the specific steps of NOR with PTP algorithms. We assume that all users issues the message request at every time slot using constant probability. Every messages have the same size and delay limit. The delay limit is the time bound that the message should be transferred completely. The mean and the variance of the future channel gain are known. Total power is invariable.

In each time slot t:

Step 1. Calculate the expected channel capacity of the user i, EC_i from now to the delay limit. We calculate the expected transmit data size using Eq. 5. $P_A$is the total power divided by the number of multi−beam.

$$EC_i = \sum_{t=t+1}^{D_i} log\ (1 + g_i(t) * P_A) \qquad (7)$$

Step 2. Compare with the remaining data size DS_i of the message of user i with the expected channel capacity. $T_i(t)$is used to judge whether user i is allocated the resource or not, considering the channel capacity and time bound from Eq. 7. If $T_i(t)$ is less than 1, the resource will be not allocated to the user i.

$$T_i(t) = EC_i / DS_i \quad (8)$$

Step 3. The selecting factor is for ordering the users. Max CNR Scheduling and ORR adopt the channel gain, and NOR adopts the normalized channel gain as the selecting factor. This method dissimilates the characteristics of NOR and ORR. ORR is different from Max CNR Scheduling by utilizing$RF_i(t)$, which is the factor to limit the number of the resource allocated time. Every round, the cells are allocated the same count. The initial value of this count varies with the fairness term. As the fairness term is shorter, the initial value is smaller, therefore all of users are allocated resource within shorter period. When user i is allocated a beam, the $RF_i(t)$ decreases by one. If $RF_i(t)$ is zero user i will not be allocated resource.

Step 4. We pick the highest selecting factor values among users, as much as the number of multi−beams. The selecting factor of NOR is calculated using Eq. 7. In Eq. 6, $RF_i(t)$ and $T_i(t)$ work as the qualification for allocation. A user, who satisfies these requirements, is granted the selecting factor. Normalized channel gain is calculated using (1).

$$SF_i = N_i(g_i(t)), \text{ if } RF_i(t) > 0 \text{ and } T_i(t) > 1.$$
$$SF_i = 0, f \quad T_i(t) < 1 \text{ or } RF_i(t) = 0 \quad (9)$$

Step 5. After which users are decided to be allocated, allocated the power to each beam using water filling algorithm to maximize the power efficiency.

Ⅳ. Simulation and Result

The simulation is intended to prove the improved efficiency and the fairness of NOR scheduling. There are two groups, which are the good channel condition and the bad channel condition. The good channel condition groups experience the line of sight signal transmission and the sparse positioned obstacles, which shade the receiving terminal. As the SNR difference between two groups is getting intense, the fairness of scheduling algorithms is more serious. The fairness is inversely proportional to the SNR difference intensity. However, the intensity of relation between the fairness and the SNR difference vary with the scheduling algorithms. The Max CNR scheduling, Opportunistic round robin and Normalized Round Robin is the order of the relation intensity. The performance of PTP algorithm is improved by the intact packet transfer rate. There are two groups with PTP and the other is not. The group, which adopts PTP, shows better performance than the other does. This result improves the

PTP scheduling reduce the meaningless data transfer and increase the effective packet transmission.

4.1 Simulation Setup

Each simulation time length is one second and the time slot length is one millisecond. Two groups have different channel characteristics to provide the performance of algorithms at different channel power gain. Total throughput and throughput fairness of Max CNR scheduling, ORR and NOR are compared with the different channel contrast for 3dB, 4.7dB, 7dB and 8.4dB. The performance of PTP algorithm is whether PTP policy is adopted or not. The Jain' s fairness index is the widely used for measuring how fairly resources are allocated to multiple users. Equation for solving Jain' s fairness index is as below.

$$F_J = \frac{\sum_{i=1}^{N} M_i}{N \sum_{i=1}^{N} M_i^2} \tag{10}$$

F_J represents the ration of user allocated resource. When $F_J = 1$, all of users served the same message data size and this is absolute fairness. As the unfairness is intense, F_J is smaller. The channel contrast among the users decreases the fairness index. The objective of NOR is to mitigate this effect.

4.2 Simulation result and analysis

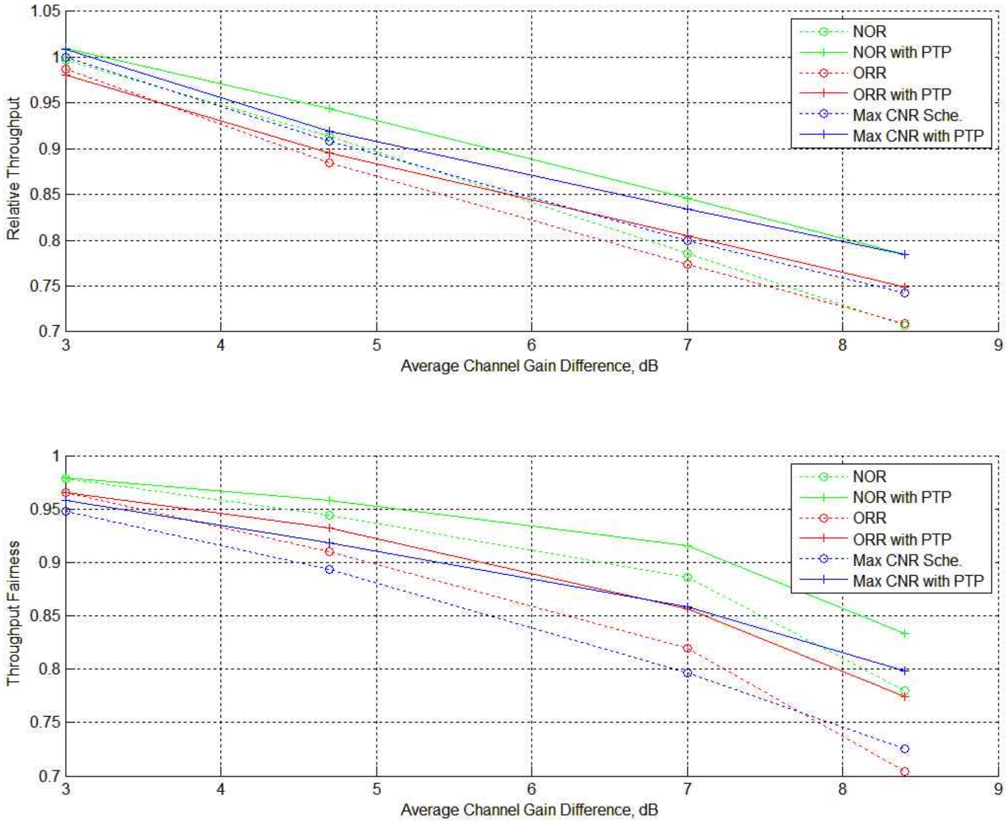


Fig. 14. The throughput and throughput fairness performance of algorithms

Max CNR scheduling policy is to choose the highest channel gain. This is effective for maximizing total throughput, but has no throughput fairness. This result is shown in Fig. 14. PTP algorithms increased others' throughput. This effect is stronger to ORR and NOR than Max CNR scheduling. The mean value difference between the channel gain of two groups reduce throughput fairness, because the user group of the lower channel gain experience intense capacity insufficiency and the some messages to these user are not transmitted. Even, when the contrast of the channels is serious, the fairness performance of NOR is relatively higher than ORR and Max CNR scheduling, besides the NOR's fairness performance is less sensitive to the channel contrast than others. The cost of implementing NOR with PUP is to know more computing resource than ORR and Max CNR.

4.3 Conclusion

In this paper, we suggest two scheduling policy for multi−beam satellite system. The first is for increasing intact packet transfer rate, and the other is increase fairness under equally allocated time slot. PTP adopted scheduling algorithms have higher intact packet transfer rate independent of the kind of scheduling algorithms. The normalized opportunistic round robin is scheduling policy, which considers the channel records to increase the performance. This algorithm has better total throughput and short−term fairness than ORR algorithm.

References

[1]Lutz, Erich, et al., "The land mobile satellite communication channel−recording, statistics, and channel model," *Vehicular Technology*, IEEE Transactions on 40.2 (1991): 375−386.

[2]Choi, Jihwan P., and Vincent WS Chan. "Optimum power and beam allocation based on traffic demands and channel conditions over satellite downlinks." *Wireless Communications, IEEE Transactions on* 4.6 (2005): 2983−2993.

[3]Can Emre Koksal, Hisham Kassab, and Hari Balakrishnan., "An analysis of short−term fairness in wireless media access protocols (poster session)," *ACM SIGMETRICS Performance Evaluation* Review. Vol. 28. No. 1. ACM, 2000.

[4]Kent, Christopher A., and Jeffrey C. Mogul., Fragmentation considered harmful. Vol. 17. No. 5. 1987.

[5]Sorour, Sameh, Shahrokh Valaee, and Nader Alagha., "Joint control of delay and packet drop rate in satellite systems using network coding," *Advanced satellite multimedia systems conference* (asma) and the 11th signal processing for space communications workshop (spsc), 2010 5th. IEEE, 2010.

[6]Kulkarni, Sunil Suresh, and Catherine Rosenberg., "Opportunistic scheduling policies for wireless systems with short term fairness constraints," *Global Telecommunications Conference, 2003. GLOBECOM'03. IEEE.* Vol. 1. IEEE, 2003.

[7]Bang, H.J.; Ekman, T., "Opportunistic Round Robin with Extended Window for Time Correlated Channels," *Vehicular Technology Conference*, 2007. VTC2007−Spring. IEEE 65th, vol., no., pp.2860, 2863, 22−25 April 2007 doi: 10.1109/VETECS.2007.587

[8] Jiang, L. B., & Liew, S. C. (2005, March). Proportional fairness in wireless LANs and ad hoc networks. In Wireless Communications and Networking Conference, 2005 IEEE (Vol. 3, pp. 1551−1556). IEEE.

요 약 문

이동위성 채널에서 균등성을 고려한 최적 자원분배알고리즘에 관한 연구

본 논문에서는 이동 위성 망에서 멀티 빔 위성을 위한 자원할당 알고리즘을 제안한다. 위성시스템에서, 효율성과 균등성은 서로 반비례 관계이다. 이러한 두 가지 성능을, 스케줄링 정책을 통해서 조정할 수 있는데 그 예가, 균등비례 스케줄링, 최대최소 균등 스케줄링 등이다. 우리는 평준기회 라운드로빈 알고리즘을 제안한다. NOR 알고리즘은 각 사용자의 채널 기록을 이용하여, 각 사용자간에 발생하는 채널이득의 평균을 보상할 수 있다. 결과적으로 NOR 은 짧은 균등화 성능에서 ORR보다 뛰어난 성능을 보여준다. 특히 각 사용자간에 채널이득의 차이가 클수록 이러한 성능차이가 발생한다. 위성 통신 서비스의 완전한 서비스를 위해서, 불완전한 패킷의 전송을 제안하고, 온전한 패킷 전송률을 늘이는 알고리즘을 제안한다. 패킷은 여러 개의 프래그맨트들로 나뉘어 전송되며, 하나의 프래그맨테이션 손실이 전체 패킷 온전한 패킷전송이 불가능하게 된다. 따라서, 완전한 패킷이 전송되려면 프래그맨테이션 손실이 없어야 하고 이러한 손실을 방지하기 위해서 패킷전송 알고리즘 (PTP)를 제안한다. PTP 알고리즘은 현재 전송하려는 패킷의 크기와 채널 용량을 고려하여, 불완전한 프래그맨테이션 전송을 제어함으로써, 전체적인 시스템 관점에서 온전한 패킷전송량을 증가시킨다. 따라서 같은 위성통신 자원을 활용하면서도, 실질 패킷 전송량은 증가하게 된다. 이러한 결과를 수학적인 수식과 시뮬레이션을 통하여 PTP 알고리즘이 패킷 프래그맨테이션이 발생하는 상황에서 성능을 향상시킴을 보인다.