# A Utility Oriented Radio Resource Management Algorithm for heterogeneous network

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## ABSTRACT

A utility oriented radio resource management algorithm is proposed for broadband nongeostationary satellite network which works in the heterogeneous network environment and provides access services for various customers on the ground. Based on the game theory, the problem for optimizing the network's performance is turned into the problem for maximizing the network's long term utility in the proposed algorithm. With evaluation to the traffic condition and dimensions of Qos for the network at the moment while the access service requirements changing, the influence of this service requirement to the long term utility of the satellite network is audited and then the resource assignment decision can be made according to the rule for maximizing the satellite network's long term utility. The process directed by game theory guaranteed both that the benefit of the network and the requirements of the customers could be considered synthetically. The simulation results demonstrate the effectiveness of the proposed algorithm.

**Keywords:** radio resource management, heterogeneous network, utility, game theory

## 1. INTRODUCTION

With the development of wireless communication technology, it is commonly agreed that the future wireless network will be an integration of all kinds of wireless network with different technologies and different service providers. Modern broadband nongeostationary satellite are developed to provide connectivity between remote terrestrial networks, direct network access, Internet services using fixed or mobile terminals, interactive multimedia applications, and high data-rate transmissions. So it is considered as the backbone network for providing satellite-based mobile multimedia services because of its low propagation delay and low path loss. This heterogeneous developing trend puts forward challenges and problems for future wireless networks resource management[1].

As the research to the resource Management for heterogeneous network has just started, the research seems concentrated in the engineering methodology such as power control, channel assignment, handover management[2]. But in fact, the objective of radio resource management for networks is not only dependent on the engineering and technical parameters such as network bandwidth, response time, delay, delay jitter, but also related with other factors such as the customers' special requirements, the customers' preferences and the prices for the services[3]. And further more the same technical parameters for Qos may cause different influences to the utility of the network for different services or just for different customers. And it is exasperated in the heterogeneous networks environments.

In this paper, a utility oriented radio resource management algorithm is proposed for broadband nongeostationary satellite network which works in the heterogeneous network environment and provides access services for various customers on the ground[4]. Based on the game theory, the problem for optimizing the network's performance is turned into the problem for maximizing the network's long term utility in the proposed algorithm. With evaluation to the traffic condition and dimensions of Qos for the network at the moment while the access service requirements changing, the influence of this service requirement to the long term utility of the satellite network is audited and then the resource assignment decision can be made according to the rule for maximizing the satellite network's long term utility. The process directed by game theory guaranteed both that the benefit of the network and the requirements of the customers could be considered synthetically. So the case could be avoided in the extent of game theory that the customers hand over to other network actively as they discontent with the satellite's Qos condition and result in directly the decrement of

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the networks benefit and long term income. And the equilibrium could be achieved ultimately between the satellite network providers seek to the long term utility and the customers' requirements to the service.

## 2. UTILITY ORIENTED RADIO RESOURCE MANAGEMENT ALGORITHMS

### 2.1 System Model

Considering a broadband nongeostationary satellite network which works in the heterogeneous network environment and provides access services for various customers on the ground[4], while the customers have the multi-access ability to access to the satellite network or other network to acquire the best service he/she regarded. There are two key steps that the satellite should decide its resource assignment results. One for the time there is a customer request to access in and the other for there is a customer departing.

Assume that the satellite has two strategies for the customer request to access to. $SS_1$ for the satellite allows the customer to access and $SS_2$ for the satellite denies the customer's request. Then the rational customer will have two strategies in the case of the satellite's decision: $CS_1$ for the customer accesses to the satellite and $CS_2$ for the customer turn to other network. The utility Matrix in this game for the game parts can be expressed as:

$$A = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}, \quad B = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \tag{1}$$

Where $a_{11}$ denotes the satellite allows the session to access and the customer access to the satellite, $a_{12}$ denotes the satellite allows the session to access in but the customer turn to other network, $a_{21}$ denotes the satellite denies the session's request but customer stay to initiate new request to access to the satellite, $a_{22}$ for the satellite denies the session's request and the customer turn to other networks. So the satellite's rational choice would be maximizing its income and the customer's rational choice would be maximizing the service's Qos level. For the sake to maximize the satellite's long term income, it must care for the customer's utility.

The resource adjusting process occurs at the time when one customer departs from the satellite's network or the traffic flow of the sessions online is changing. When one customer departs from the satellite's network, it will return the resource it has seized to the satellite. To simplify the analysis process, assumed that in the process of resource allocation, the satellite could only allocate the spare resources to the customers in one-by-one mode according to the service level and accessing order. Then the satellite will have two candidate strategies of resource allocation for the $j$th customer in the n customers online. $S_{j1}$ denotes the satellite will increase the resources allocated to the $j$th customer; $S_{j2}$ denotes the satellite will maintain the original resources for the $j$th customer. On the other hand, the $j$th customer has two corresponding strategies: $CS_{j1}$ for the $j$th customer remains connect to the network and $CS_{j2}$ for disconnect from the network. Then the satellite and the customer's rational behavior could be analyzed in the same way with the access control scheme.

In the same way, it can be verified that the process for decreasing the resource allocated for a customer is just the process for minimizing the lost for the customer's utility. Based the analysis of this section, a resource management algorithm for the satellite working in the heterogeneous environment is proposed in the next sub-section below.

### 2.2 Utility Oriented Radio Resource Management Algorithms

Step 1: Initiating the system's resource management algorithm's parameters such as the types of the system resource $\mathrm{RK}_{\max}$, the traffic parameters for the systems service providing like $\lambda^S$, $m_l^S$, $m_d^S$ and the price parameters for all kinds of service $P(k_j)$.

Step 2: When a new session arrives, the satellite will check the system state and compare the resources required for the new session $R(n)_{\max}$ and the system's remaining resources parameters $RS_{rest}$.

Step 2.1 If $RS_{rest} \geq R(n)_{\max}$, the system is in the state of *unfully-loaded* and will allow new session to access in and will satisfy the greatest resource requirements from the new session.

Step 2.2 If $RS_{rest} < R(n)_{\max}$ , the system is in state of *fully-loaded* state.

Step 2.2.1 From the types of services $K_j = 1 : K_{max}$, the corresponding service level is $Q(K_j)= Q(1): Q(K_{max})$ (assuming the service with higher type number has higher utility/service-level ratio). Compares the system utility $US(n)_{min}$ bring with the minimum resources for the new session with the utility loss as the other session be deprived of the resources it has occupied $(US(\sum Q(K_j(i-1)))-US(\sum Q(K_j(i-1))))$. If the utility loss is less than the expected the utility gain, deprive one lot of resource from the corresponding session and reallocate it to the new session.

Step 2.2.2 In the case of all sessions online have been reduced to the lowest level of service and cannot satisfy the new sessions lowest request, the new session is blocked immediately.

Step 3: When a session is departing (include disconnecting and handing over), it will release system resource to $RS_{rest}$ . Check the current system state.

Step 3.1 If the system is in state of *unfully-loaded* , means that all existing sessions are at the highest level of service, then do nothing except continuing process cycle.

Step 3.2 Otherwise, from the types of services $K_j = K_{max} : 1$, do compare the $RS_{rest}$ with increasing level request $R(K_j)$ to the system resource of the session for increasing the system utility. If it is larger than the request, reallocate the corresponding resource to the session to increase its service Qos level and to increase the user's utility and the system utility in the same time.

Step 3.3 In the case of all sessions online have been increased to the highest level of service and there is spare resource left, the system is turn into *unfully-loaded* state again.

Step 4: When a session's traffic flow has increased, the satellite will check the system state and compare the increased resources requirement for the session $R(n)_{\Delta}$ and the system's remaining resources parameters $RS_{rest}$ .

Step 4.1 If $RS_{rest} \geq R(n)_{\Delta}$ , the system is in the state of *unfully-loaded* and will allow new session to access in and will satisfy the greatest resource requirements from the session.

Step 4.2 If $RS_{rest} < R(n)_{\Delta}$ , the system is in state of *fully-loaded* state. Reallocating the system resource in all online sessions like Step 2.2.1. From the types of services $K_j = 1 : K_{max}$, compares the system utility $US(n)_{delta}$ bring with the resources for the session with the utility loss as the other session be deprived of the resources it has occupied $(US(\sum Q(K_j(i-1)))-US(\sum Q(K_j(i-1))))$. If the utility loss is less than the expected the utility gain, deprive one lot of resource from the corresponding session and reallocate it to the session which is requesting more system resource.

Step 5: When a session's traffic flow has decreased, it will release system resource to $RS_{rest}$ . Check the current system state.

Step 5.1 If the system is in state of *unfully-loaded*, means that all existing sessions are at the highest level of service, then do nothing except continuing process cycle.

Step 5.2 Otherwise, from the types of services $K_j = K_{max} : 1$, do compare the $RS_{rest}$ with increasing level request $R(K_j)$ to the system resource of the session for increasing the system utility. If it is larger than the request, reallocate the corresponding resource to the session to increase its service Qos level and to increase the user's utility and the system utility in the same time.

Step 5.3 In the case of all sessions online have been increased to the highest level of service and there is spare resource left, the system is turn into *unfully-loaded* state again.

Step 6: Go to Step 2

## 3. SIMULATIONS AND RESULT ANALYSIS

Assume that in the coverage district of the satellite there are 1,000 customers. According 3GPP service model, there are four types of services provided: Background Service-such as Email, files download, measurement data transmission etc, Interactive Service-including Web browsing, database accessing and retrieving, Streaming Service-currently showed as the real-time audio and video streaming Service, Conversational Service-including circuit-switching telephone, packet-switching phones, video conference, network games and other delay-sensitive applications. To facilitate the verification and analysis, we take the circuit-switching telephone service apart from the fourth type of service. So there are 5 types of services ranks from low to high of resource/price ratios. The Class 1 is Background Service (BS). Class 2 is Interactive Service (IS). Class 3 is circuit-switching telephone service (Phone). Class 4 is Streaming Service (SS). Class 5 is Conversation service (CS). Assume the observing period duress 3600 seconds and the QoS requirements and traffic parameters for these services are shown in Table 1 and Table 2.

Table 1. The services' QoS requirements parameters

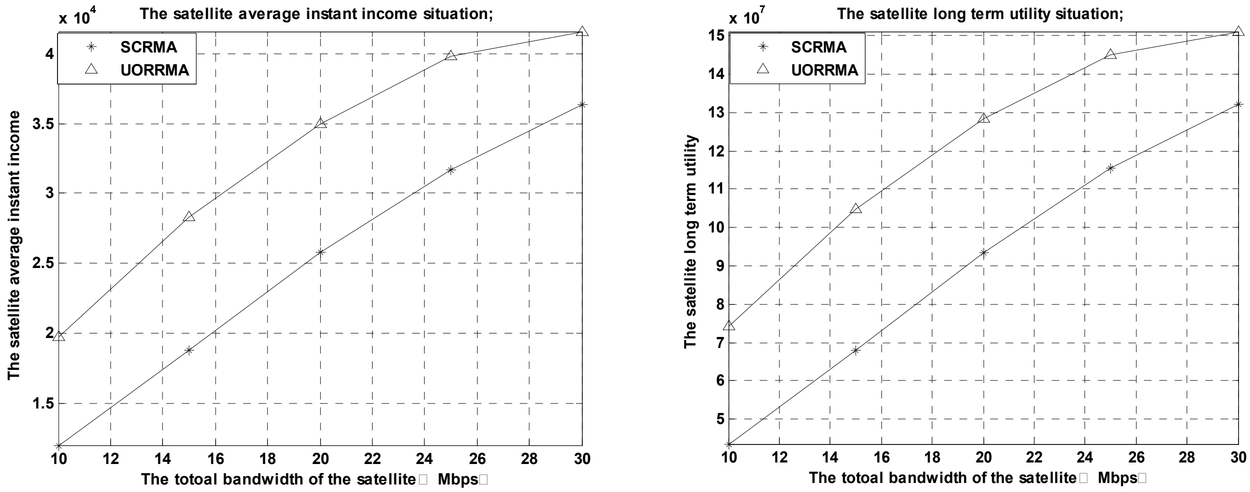
| Service Type | Delay(ms) | Uplink flow rate /( Kbps) | downlink flow rate /( Kbps) | jitter(ms) |
|---|---|---|---|---|
| Phone | <50 | 64 | 64 | 5. 0 |
| CS | <50 | 80 | 512~6000 | 5. 0 |
| SS | <1000 | 64 | 10000 | 05 |
| IS | <100 | 2000 | 8000 | 10. 0 |
| BS | <5000 | 64 | 64 | — |

Table 2. The services' traffic parameters

| Service Type | Lowest flow rate/( Kbps) | Highest flow rate /( Kbps) | flow rate step | Average duration（s） | Average flow rate | Hand over rate | λ |
|---|---|---|---|---|---|---|---|
| Phone | 64 | 64 | 0 | 180 | 11520 | 0.1 | 2 |
| CS | 1000 | 6000 | 1000 | 2000*15*60 | 1800000 | 0.05 | 0.2 |
| SS | 500 | 10000 | 500 | 10 | 100000 | 0.05 | 0.5 |
| IS | 100 | 8000 | 100 | 100*10 | 1000 | 0.1 | 5 |
| BS | 0 | 64 | 1 | 1/64 | 1 | 0.1 | 20 |

Based the above hypothesis, simulation is done aim to compare of the systems instantaneous utility in simple channel reserved management algorithm(SCRMA) and Utility Oriented Radio Resource Management Algorithm(UORRMA). The result of the system average instant income and long term utility in different traffic scenarios for these algorithms is shown in figure 1.

Figure 1 shows that the Utility Oriented Radio Resource Management Algorithm acquires the better average instantaneous income and better long term system utility. Especially in the scenarios of the system resources is constrictive for the customers requirements when the bandwidth of one beam of the satellite is 10 Mbps ~ 15M bps, the UORRMA's average instantaneous income and cumulative income is far higher than the simple management algorithm, get to about two to three times. When the system is *unfully-loaded*, the system long term utility is decided by the total summation of the income from the online services that be allowed to access. When the system is *fully-loaded*, the loss in system long term utility is not only the instant income loss as for low quality service but should consider the loss in customer loyalty as received low quality service and the further influence on the system long-term revenue. For simplifying the analysis process, the loss in system long term utility is defined ratio to the loss of the system instant income. Here, we choose the coefficient = 5. And in the same reason, the coefficient for the loss in customer loyalty as for rejecting customer to access is defined as 10. Figure 1(b) shows the simulation result of the system long term utility in various traffic distributions in observation time. The figure shows that the UORRMA has gained the better result as it has improved the system bandwidth utilization with more scaling strategies, lowered the drop rate and blocking rate of the sessions , so brings more benefit to the customer's utility and to the system long term utility too.




(a) Instantaneous average income

(b) System long term utility

Fig.1. Instantaneous and average income of system long term utility

With the definition that the dimension for the customer's satisfaction to the system's Qos be expressed as the expression below[5]:

$$st\_uu\_qos(C_t, C_i) = uu + bs + dl + uuf = w_{uu}(typ) \cdot RK_{uu} + w_{bs}(typ) \cdot RK_{bs} + w_{dl}(typ) \cdot RK_{dl} + w_f(typ) \cdot RK_f \quad (2)$$

While $st\_uu\_qos(C_t,C_i)$ denotes the dimension for the *ith* customer's satisfaction to the system's Qos at the time *t.* And it is decided by the combination of four factors of: the *ith* customer's utility, the bandwidth satisfaction of the *ith* customer's current service, the average delay of this customer's service and the dimension for the fairness of the customer's utility. And the value for each factor is related with the specific service and corresponding coefficient.

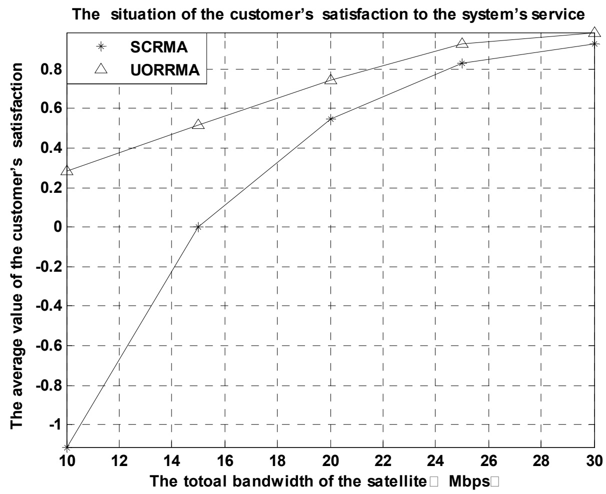



Fig.2. The customer's satisfaction to the Qos of the system

The simulation result is shown in Figure 2. It can be seen because the UORRMA takes the system long term utility as the optimizing goal, and the long term utility depend in some extent on the factor of the customer's utility, it acquires the optimized system utility and optimal customer utility at the same time.

## 4. CONCLUSIONS

Based on the game theory, the problem of radio resource management for broadband nongeostationary satellite network which works in the heterogeneous network environment for various customers on the ground is researched and a utility oriented algorithm is proposed. With evaluation to the traffic condition and dimensions of Qos for the network at the moment while the access service requirements changing, the influence of this service requirement to the long term utility of the satellite network is audited and then the resource assignment decision can be made according to the rule for maximizing the satellite network's long term utility. The process directed by game theory guaranteed both that the benefit of the network and the requirements of the customers could be considered synthetically. The simulation results demonstrate the effectiveness of the proposed algorithm.

## REFERENCE

1. Ibnkahla, M.; Rahman, Q.M.; Sulyman, A.I.; Al-Asady, H.A.; Jun Yuan; Safwat, A., "High-speed satellite mobile communications: technologies and challenges," Proceedings of the IEEE, 92(2), 312-339(2004) .

2. Jihui Zhang, Jinpeng Huai, Renyi Xiao, Bo Li, "Resource management in the next- generation DS-CDMA cellular networks," IEEE Wireless Communications , 11(4), 52-58(2004) .

3. Wei Song, Hai Jiang, Weihua Zhuang, and Xuemin (Sherman) Shen, "Resource Management for QoS Support in Cellular/WLAN Interworking," IEEE Network , 19(5), 12-18(2005) .

4. WANG Xiao-yan,WANG Hao, DONG Yan, HUANG Zai-lu, "Networking model and traffic analysis for integrating Ad hoc and LEO satellite terminals," *Journal on communications*, 27(8), 139-143(2006) .

5. Sajal K. Das and Haitao Lin, "An Econometric Model for Resource Management in Competitive Wireless Data Networks," IEEE Network , 18(6), 20-26 (2004) .