A Novel Access Protocol for Communication System in Near Space

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***Abstract*—The calling of users is very uneven and the channel collision detection ability is quite weak in communication system in near space (CSNS). To ensure quality of service (QoS), a novel load measurement access control (LMAC) protocol is proposed. Combined with Markov M/M/n queue model, integrated theoretical analytical model is established for CSNS. The effect which the waiting probability of calling service, calling number and measure parameter have on the performance of the networks are analyzed. Besides, the LMAC scheme is introduced to greatly increase the maximum throughput to 0.33 and improves the maximum throughput nearly one time compared to the maximum throughput 0.18 of the simple ALOHA protocol and closed to the theoretical bound.**

Keywords-communication system in near space; load measurement access control; performance; throughput

I. INTRODUCTION

An area called near space is away from the earth ranging from 20 to 100 kilometers which is in the middle of the biggest height of the plane flying and the smallest height of the satellite moving. Now the near space has been concentrated on research because of important values in military and application. Recently many research centers including US military are researching the near space communication because of many merits such as low expense, fast deployment, convenient retrieve and so on [1-3]. The characteristics of channel in near space are different from point-to-point channel, broadcast channel and point-to-multipoint channel controlled by base station in cellular mobile communication system. The channel in near space takes on space re-use character, on the other hand, frequency re-use and interference in the terminal will bring about package collision and fall of channel utilization [4]. Wireless link capacity will change with time because of change of network topology and wireless channel attenuation [5]. The calling of user is very uneven and the channel collision detection ability is quite weak in CSNS. To ensure the quality of service, a novel load measurement access control (LMAC) protocol is proposed. It depends on the load evaluation by measurement for the new user's access to network in near space. Many merits are brought by this new protocol for avoiding establishing complicated model for different services. Many hypotheses for services are avoided and description for service is simplified. Consequently quality of service (QoS) is improved and service requirement is sufficed to network in near space sufficiently.

The remaining part of this paper is comprised as follows. In section 2, network structure and characteristics are described for LMAC protocol derivation. In section 3, integrated theoretical analytical model is established for CSNS. Finally simulation results are analyzed and some key conclusions are given.

II. NETWORK STRUCTURE

Figure 1 shows the wireless CSNS which are comprised by high altitude platform with communication equipment, controlled system on the ground and various mobile users. The CSNS can be comprised by only one switch node which covers an area to ensure various kinds of services transmitted successfully. Also the CSNS can be comprised by many switch nodes which improves the ability to resist damage and extend the networks in the ground.

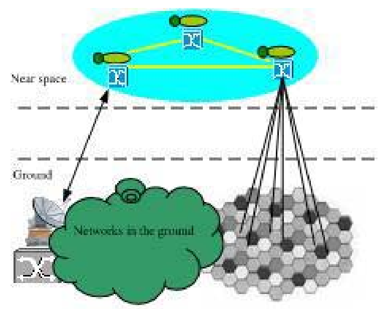

Figure 1. Network structure of CSNS

The main idea of the LMAC protocol is described as follows. Center switch platform in near space will calculate access probability by network load measurement. Access process will be operated according to the broadcast access probability that user received. Certainly access probability depends on the channel load. Access probability decreases when the channel load is higher than the threshold that is defined in advance. As well as the access probability increases when the channel load is lower than the threshold. Therefore the center switch platform will calculate the access probability according some algorithm by channel load measurement. The optimized probability will be broadcast to

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every access user and the performance of the network will reach optimization consequently.

III. THEORETICAL ANALYSIS

Some hypotheses are made in advance in order to simplify the research difficulty. Every call arrival time and service duration time obey minus exponent distribution. N calls wait for access the network equally. Considering that the network is balanced and every user in near space has the same behavior and character. Therefore we introduce the Markov M/M/n queue model to analyze the user's call character in near space.

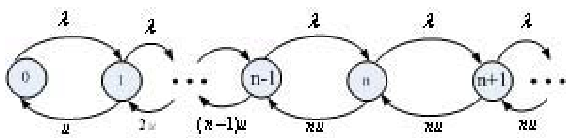

Figure 2. M/M/n queue

In Figure 2, λ is user arrival probability, u is the user average service probability that is provided by the switch platform. Considering that switch platform is independent of each other. Therefore the user average service probability is same ($u_1 = \ldots = u_n = u$) and state transfer probability is showed in equation (1).

$$\begin{cases} \lambda_j = \lambda & j = 0,1. \;\; .. \\ u_j = \begin{cases} ju & j = 1,\ldots,n-1 \\ nu & j = n, n+1,\ldots \end{cases} \end{cases} \quad (1)$$

Lemma1 [6-7]: Considering M/M/n model and steady state Kovmogorov equation [8], if *n* users are waiting for service in queue in a network with *N* users, the *j*th user's service probability is:

$$\begin{cases} P_0 = \left(\sum_{j=0}^{n-1} \frac{(n\rho)^j}{j!} + \frac{(n\rho)^n}{n!(1-\rho)}\right)^{-1} \\ p_j = \begin{cases} \frac{(n\rho)^j}{j!} P_0 & j = 1,\ldots,n-1 \\ \frac{(n\rho)^j}{n!\,n^{j-n}} P_0 & j = n, n+1,\ldots \end{cases} \end{cases} \quad (2)$$

Where $\rho = \lambda/(nu)$ is average service density.

A. Access process

LMAC method is introduced to CSNS and system time is divided into some time slots. Data packages are transmitted at the beginning of the time slot. The time slot is slightly longer than the transmitted time of data package. Therefore the data packages and control information can be transmitted reliably. At the interval of time slot the optimized access probability is broadcast to every access station which will transmit data package.

Access process can be completed by the cooperation of switch platform and terminals. The access process of the terminal is described particularly in Figure 3.

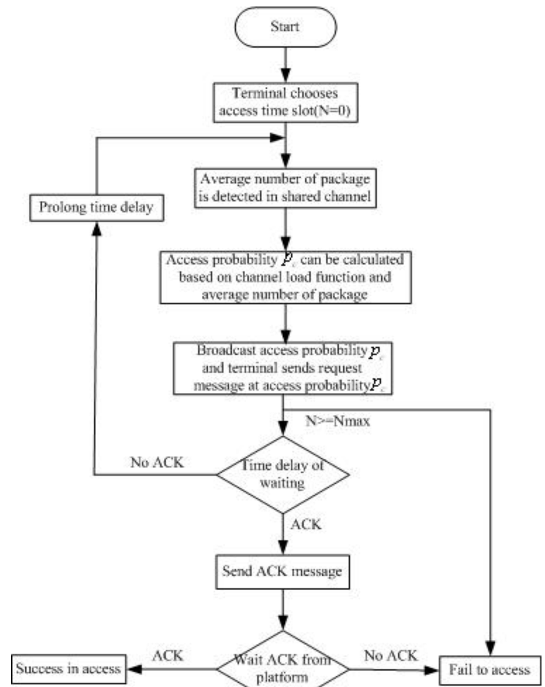

Figure 3. Diagram of accessing process

The performance of LMAC protocol depends on the channel load. Therefore the correctness of the channel load evaluation is of importance to the access probability. In the following we describe how to obtain the optimized access probability. Supposed that $\lambda(t)$ is expected arrival ratio in the time period *t*. Thus, the number of packages in time period ($t+\tau$) will be measured by the following equation.

$$L_t = \int_t^{t+\tau} \lambda(v)dv \quad (3)$$

Considering that P_c will be effective in the τ time periods. Hence, the change of arrival ratio $\lambda(t)$ will be small as possible in the τ time periods. $L_{\max}$, $L_{\min}$ and $E[L]$ are maximum, minimum and average value in the τ time periods respectively. In order to get the optimized access probability P_c, τ will be small enough to satisfy $(L\max - L\min)/E[L]$ to reach minimum value.

B. Throughput analysis

n is the users' number of calling waiting for service and normalized throughput can be described in equation (4)

$$S(n) = \sum_{j=0}^{N} (p_{n,n-1} + np_c(1-p_c)^{N-1}) \quad (4)$$

Where $p_{n,n-1}$ is one user's successful transmission probability in n waiting users; p_c is optimized access probability which is controlled by center switch platform in near space. For wireless network, generally $p_c = \frac{1}{\alpha N}$ $(0 \le \alpha)$, α is measure parameter for access probability. Combined with equation (4):

$$S(n) = \frac{1}{\alpha}\left(\frac{\alpha N - 1}{\alpha N}\right)^{N-1} \tag{5}$$

C. Waiting probability of calling service

In LMAC protocol λ is user's arrival probability, u is the average service probability of user from switch platform. Thus, the average number of waiting for calling service is:

$$L_q = \sum_{j=1}^{\infty} jP_{n+j} \tag{6}$$

Combined with lemma 1, the simplified average number is:

$$L_q = \frac{(n\rho)^n \rho}{n!(1-\rho)^2} P_0 \tag{7}$$

Hence , waiting probability for call service is:

$$P_n = \rho^n \frac{(1-\rho)}{1-\rho^{m+1}} \tag{8}$$

IV. Results Analysis

We refer to many literatures which presented the definition of parameters in wireless mobile networks. Therefore we define that the number of switch platform is 3, access speed of user is 64Kbps, channel rate is 2Mbps and average service time of user is 60s respectively.

A. Measure parameter's effect on performance of the networks

Figure 4 shows the relationship between normalized throughput and measure parameter (N=5, 10, 15). It is clear that normalized throughput will reach the theoretical maximum if the channel load is measured precisely. LMAC protocol is based on the channel load measurement. The LMAC scheme is introduced to greatly increase the maximum throughput to 0.33 and improves the maximum throughput nearly one time compared to the maximum throughput 0.18 of the simple ALOHA protocol.

B. Waiting probability's effect on performance of the networks

Figure 5.a shows the relation between throughput and waiting probability of calling service. We can easily find that the throughput increases with the augment of the waiting probability of calling service. Network takes on an excellent performance when waiting probability is about 0.35. This phenomenon can be explained that the number of the users in network is appropriate, collision is relatively few and network performance reaches peak state. The throughput decreases if the N value increases continuously. At the same time we describe the relation between network user capacity and throughput under different N value.

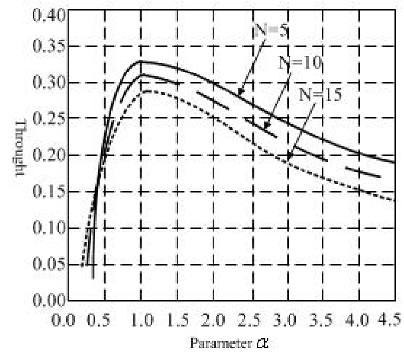

Figure 4. The relation between throughput and measure parameter α

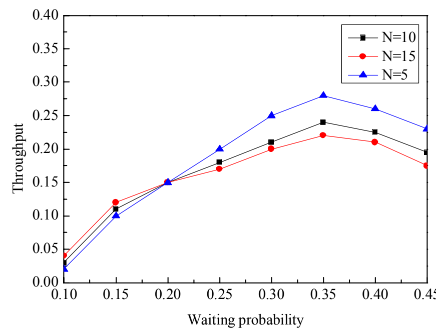

Figure 5.a. Throughput VS waiting probability of calling service

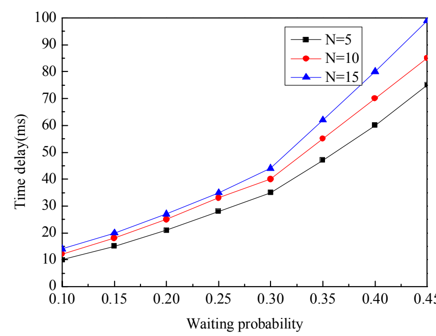

Figure 5.b. Time delay VS waiting probability of calling service

Figure 5.b shows the relation between average time delay and waiting probability of calling service. We can easily find that the average time delay increases with the enhancement of the waiting probability of calling service. The time delay increases sharply if the waiting probability of calling service increases continuously. It shows that network's performance runs down, the access probability decreases, network congestion is serious when the waiting probability of calling service increases. Moreover, time delay increases sharply when waiting probability of calling service is over 0.3. In

order to access the network more quickly, the user's waiting probability of calling service must be under 0.3.

C. Call number's effect on the performance of the network

Figure 6.a shows the relation between throughput and the number of user's calling. Network throughput decreases with the augment of the calling number. We also can easily find that network throughput decreases sharply when the calling number is over 15. Therefore in CSNS calling threshold should be set less than 15 for user's successful access to the network. Otherwise large number of calling occupies network resource and the performance is worsened sharply.

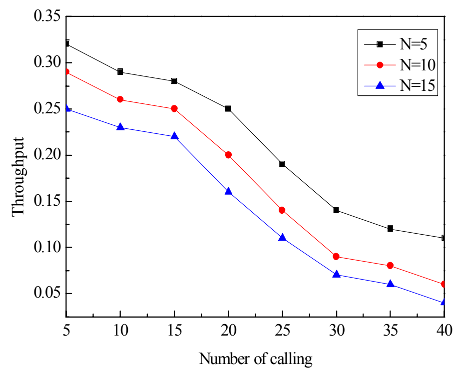

Figure 6.a. Throughput VS calling number

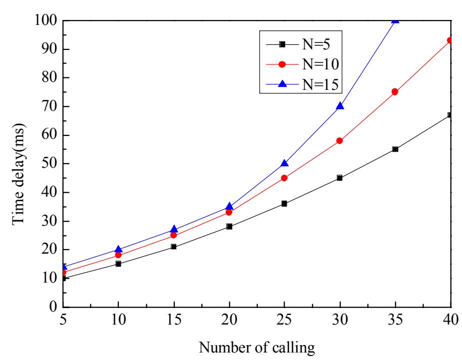

Figure 6.b. Time delay VS calling number

Figure 6.b shows the relation between average time delay and the number of user's calling. The network time delay increases when calling number increases. Moreover, time delay increases sharply when calling number increases sequentially. When the calling number is over 20, the time delay begins to decrease sharply. Therefore user can quickly access to CSNS when calling number is under 20. This is very close to the result in Figure 6.a.

V. CONCLUSIONS

This paper provides LMAC protocol combined with Markov M/M/n queue model. Integrated theoretical model for CSNS is established and the structure and characteristics are described clearly. The effect which the waiting probability of calling service, calling number and measure parameter have on the performance of the networks are analyzed. Above all, some important conclusions are given: (1) Calling threshold should be less than 15; (2) Waiting probability of calling service should be less than 0.35; (3) The LMAC scheme is introduced to greatly increase the maximum throughput to 0.33 and improves the maximum throughput nearly one time compared to the maximum throughput 0.18 of the simple ALOHA protocol.

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