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Analysis and Research on Polling Scheduling Algorithm of Intelligent Distribution Network System

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ABSTRACT: Ethernet passive optical network (EPON) is an important development direction for the construction of intelligent distribution network access layer communication system. According to the service quality requirements of each service of smart distribution network, especially the development of new protection and control technology based on network communication, a scheduling-based asymmetric polling control algorithm is proposed. The arrival time of the information packet entering the queue at any time, the query conversion time between the service time and the queue is a random variable, and the arrival time of the information packet of the optical line terminal to the queue is confirmed on the basis of ensuring the EPON polling rate. The service time and the query conversion time between the queues are dynamically allocated to better meet the actual communication requirements of different services. In addition, for the proposed dynamic scheduling algorithm, the mathematical model of the system is established by combining the Markov chain and the probabilistic parent function. For its partial guidance, several important system operating parameters such as the system's circular query period, average queue length and average waiting delay are analyzed. The theoretical calculated values are approximately consistent with the simulated simulation values, indicating the correctness of the theoretical analysis method. Compared with the symmetric full service system, the asymmetric system is more suitable for the actual communication requirements of different services and multi-channel multiple access.

Keywords: intelligent distribution network; asymmetric; polling; multiple access

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I. INTRODUCTION

The intelligent distribution network is characterized by information, digitization, automation and interaction. Through the high integration and sharing of multi-source information and deep mining and utilization, the intelligent dispatch control of the distribution network and the deep interaction between the user and the grid are realized. Scaled flexible access to distributed power supplies [1-2]. Compared with the traditional distribution network, the communication service demand of the intelligent distribution network has increased significantly. Especially with the continuous increase of the distributed power supply penetration rate, the new protection technology based on network communication will be gradually promoted and applied to solve the traditional protection. Many difficulties, such as difficulty in setting and lowering sensitivity, have also put forward higher requirements for the quality and real-time performance of communication services in smart distribution networks [3-4]. Intelligent distribution network terminals have a large number and wide distribution. Ethernet passive optical network (EPON) is a new type of communication technology. It has become a smart because of its low cost, high bandwidth, and strong scalability. One of the important choices for the access layer of distribution network communication systems. One of the main problems that EPON technology needs to solve in engineering applications is how to ensure various types of service requirements and multi-channel multiple access technologies through flexible and reasonable load scheduling algorithms. So far, many scholars have carried out various research work on the engineering application of EPON technology. Literature [5] proposed a bandwidth allocation scheme based on IPACT estimation for EPON technology applied to the “last mile” of public telecommunication network; literature [6] proposed a consideration of service quality for different network requirements of different services. , Qos) dynamic bandwidth allocation scheme for demand; literature [7] establishes the average delay model for each service of EPON system under different dynamic bandwidth allocation schemes. However, most of the above studies are aimed at telecommunication networks, and do not consider the characteristics and practical requirements of smart distribution network communication services; the literature [8] discusses the framework, functions and implementation schemes of the intelligent distribution network unified information system; [9] The construction mode and transmission service type of EPON access distribution network are studied. However, these studies do not address the rational allocation strategy of EPON system bandwidth resources, especially to ensure that various types of service requirements are met, as well as multi-channel multiple access technology.

Aiming at the above problems, this paper proposes an asymmetric full service polling control system. The arrival time of the information packets entering the queue at any time, the query conversion time between the service time and the queue are randomly variable. The bandwidth of each service is dynamically allocated to meet the application requirements of different communication services, especially relay protection and high real-time communication services. At the same time, the system model is deeply analyzed by the combination of Markov chain and probabilistic parent function. The correct and reasonable theoretical analysis is verified by simulation experiments. The model satisfies various business requirements and multi-channel multi-access. Into technology.

II. SYSTEM MODEL

2.1 Model Principle Description

The system contains N queues and a server as shown in Fig. 1. The server first serves queue 1 and then serves queue 2, That's: $1 \to 2 \to 3 \to i \to ... \to N$. For asymmetric services: the arrival rate λ_i of packets entering each queue, the service time β_i and switch-over time γ_i are all randomly variable. The server sends packets stored in each queue according to exhaustive service.

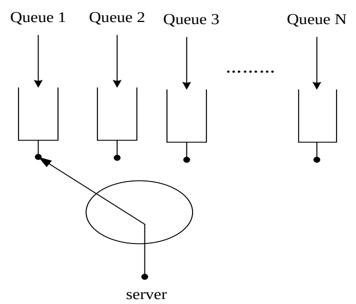

Figure 1: polling control model.

2.2 System Variable Definition

Assuming that the server begin to service queue i $(i=1,2,...,N)$ at t_n , the number of packets contained in the i queue is $\xi_i(n)$, then the status of the entire polling system at t_n can be represented as{ $[\xi_1(n), \xi_2(n).....\xi_N(n)]$ }. Denote $\xi_i(n+k)$ as the number of packets contained in the i queue at t_{n+k} , the status of the entire polling system at t_{n+k} can be represented as{ $\{\xi_1(n+k), \xi_2(n+k)\xi_3(n+k), \cdots, \xi_N(n+k)\}$. The number of queues in the polling model is relatively determined, and the status of the model at the beginning of the service is countable. The discrete Markov status variables can form an embedded Markov chain. Under the stable conditions of the model, the Markov process is homogeneous, irreducible, aperiodic, and has a unique steady-state distribution.

1): The packets arriving at each queue according to an independent Poisson process[8]. The generaing function is $A_i(z_i)$, the arrival rate of $\lambda_i = A_i'(1)$, with the variance of $\sigma_{\lambda i}^2 = A_i''(1) + \lambda_i - \lambda_i^2$;

2): The service time of a packet at each queue is independent of each other. The generaing function is $B_i(z_i)$, the mean value $\beta_i = B_i'(1)$, with the variance of $\sigma_{\beta i}^2 = B_i''(1) + \beta_i - \beta_i^2$;

3):The switch-over time between queues is independent of each other. The generaing function is $R_i(z_i)$, the mean value is $\gamma_i = R_i'(1)$, the variance is $\delta_{\gamma i}^2 = R_i^{*}(1) + \gamma_i - \gamma_i^2$;

4): The memory in each queue has enough buffer capacity, and no packets loss occurs;

5): In-memory packets are sent according to the first-come-first-serve (FCFS) policy.

6): $u_i(n)$: The switch-over time between queues; $\eta_j(v_j)$: the number of packets entering the *j-th* queue during $\mu_i(n)$ time.

2.3 Probability Generating Function

Under the necessary and sufficient condition for the stability [10] of the system $\sum_{i=1}^{N} \lambda_i \beta_i = \sum_{i=1}^{N} \rho_i < 1$, the probability distribution is:

$$p[\xi_i(n) = x_i; i = 1,2,3,...N,h] = \pi_i(x_1, x_2, ..., x_N, x_h)$$
$$p[\xi_i(n^*) = y_i; i = 1,2,3,...N,h] = \pi_{ih}(x_1, x_2, ..., x_N, x_h)$$
(1)

The probability generating function of $\pi_i(x_1, x_2, ..., x_N, x_h)$ is:

$$G_i(z_1, z_2, \cdots, z_N) = \sum_{x_1=0}^{\infty} \sum_{x_2=0}^{\infty} \cdots \sum_{x_N=0}^{\infty} \pi_i(x_1, x_2, \cdots, x_N) \cdot z_1^{x_1} z_2^{x_2} \cdots z_N^{x_N}$$
(2)

According to the definition of the probability generating function, the probability generating function of state variable of system when polling queue of $i+1$ at time t_{n+1} is:

$$G_{i+1}(z_1, z_2, ...z_N, z_h) = \lim_{t \to \infty} E[\prod_{i=1}^{N} z_i^{\xi_i(n+1)} z_h^{\xi_h(n+1)}]$$
(3)

It is known that there are the following relationships：

$$\begin{cases}\xi_i(n+1)=\xi_i(n)+\eta_j(\upsilon_j)\\ \xi_j(n+1)=\eta_i(\upsilon_j)\end{cases}$$
(4)

From(1)(2)(3) (4),we obtain probabilistic generating function [8]:

$$G_{i+1}(z_1,z_2,\cdots,z_i,\cdots,z_N)=\lim_{n\to\infty}E[\prod_{j=1}^{N}z_j^{\xi_j(n+1)}]=$$
$$R[\prod_{j=1}^{N}A(z_j)]G_i[z_1,z_2,\cdots,z_{i-1},B(\prod_{\substack{j=1\\ \neq i}}^{N}A(z_j)F(\prod_{\substack{j=1\\ \neq i}}^{N}A(z_j))),z_{i+1},\cdots,z_N]$$
(5)

III. MODEL THEORETICAL ANALYSIS

3.1 Average Queue Length

Average queue length is defined as number of packets in queue j when queue i begins to be served at the time t_n.

$$g_i(j)=\lim_{z_1,z_2,\cdots,z_N\to 1}\frac{\partial G_i(z_1,z_2,\cdots,z_N)}{\partial z_j}$$
(6)

According to (6), derivative of (5), We can obtain the average queue length:

$$g_i(i)=\frac{\lambda_i(1-\lambda_i\beta_i)\sum_{j=1}^{N}\gamma_j}{1-\sum_{j=1}^{N}\lambda_j\beta_j}$$
(7)

3.2 Average Cycle

Average cycle is defined as the period between two polls for one queue. Similarly it can be derived from (5) as follows:

$$\theta=\frac{\sum_{i=1}^{N}\gamma_i}{1-\sum_{i=1}^{N}\lambda_i\beta_i}$$
(8)

3.3 Throughput

System throughput is defined as the number of packets that the system can serve in a unit time. Similarly it can be derived from (5) as follows:

$$T=\sum_{i=1}^{N}\lambda_i\beta_i$$
(9)

3.4 Average Waiting Time

Average waiting time denotes the time from the epoch when a packet arrive at the queue to the time it is served.

The second derivative of system is defined as:

$$g_i(j,k)=\lim_{z_1,z_2,\cdots,z_j,\ldots,z_N,z_h\to 1}\frac{\partial^2 G_i(z_1,z_2,\cdots,z_j,\ldots,z_N,z_h)}{\partial z_j\partial z_k}$$
(10)

According to (10), derivative of (5),we obtain:

$$g_{i+1}(j,j)=\lambda_j^2R_i''(1)+2\lambda_j\gamma_i g_i(j)+[\frac{2\lambda_j^2\beta_i\gamma_i}{1-\rho_i}+\frac{\beta_i(1-2\rho_i+2\rho_i^2)A_j''(1)}{(1-\rho_i)^3}$$
$$+\frac{\lambda_j^2\beta_i^3A_i''(1)}{(1-\rho_i)^3}+\frac{\lambda_j^2B_i''(1)}{(1-\rho_i)^3}]g_i(i)+g_i(j,j)+\frac{\lambda_j^2\beta_i^2}{(1-\rho_i)^2}g_i(i,i)$$
(11)

$$g_{i+1}(j,i)=\lambda_i\lambda_jR_i''(1)+\lambda_i\lambda_j\gamma_i+\lambda_j\gamma_i g_i(j)+\frac{\lambda_j\gamma_i\rho_i}{1-\rho_i}g_i(i)$$
(12)

$$g_{i+1}(i,i)=\lambda_i^2R_i''(1)+\gamma_iA_i''(1)$$
(13)

$$g_j(j,j)=\lambda_j^2\sum_{i=1}^{N}R_i''(1)+\lambda_j^2\sum_{i=1}^{N}\gamma_i+\lambda_j^2\sum_{\substack{i=1\\ \neq j}}^{N}[\frac{2\beta_i\gamma_i}{1-\rho_i}+\frac{2\beta_i\rho_i}{1-\rho_i}+\frac{\beta_i(1-2\rho_i+2\rho_i^2)}{(1-\rho_i)^3}$$
$$+\frac{B_i''(1)}{(1-\rho_i)^3}]g_i(i)+2\lambda_j\sum_{\substack{i=1\\ \neq j}}^{N}\frac{\beta_i}{1-\rho_i}g_i(j,i)+\lambda_j^2\sum_{\substack{i=1\\ \neq j}}^{N}\frac{\beta_i^2}{(1-\rho_i)^2}g_i(i,i)$$
(14)

According to (11) (12) (13) (14), we obtain:

$$(1-\sum\rho_i)\sum\frac{\beta_i}{\lambda_i(1-\rho_i)}g_i(i,i)=\sum\rho_i\sum R_i''(1)+\sum\rho_i[(\sum\gamma_i)^2-\sum\gamma_i^2]+$$
$$\theta\{\sum\frac{\lambda_iB_i''(1)}{1-\rho_i}-\sum\frac{\lambda_i\rho_iB_i''(1)}{1-\rho_i}+\sum\gamma_i[(\sum\rho_i)^2-\sum\rho_i^2]-(1-\sum\rho_i)\frac{\rho_i^2}{1-\rho_i}\}$$
(15)

3.5 Approximation Method

Define variables $\theta_i(z_i)$ related to the cycle period, they satisfy the following equation:

$$\theta_i(z_i)=G_i(1,\cdots,z_i,1,\cdots,1)$$
(16)

Calculate second derivative of (16) we obtain:

$$\lambda_i^2\theta_i''(1)+\theta A_i''(1)=g_i(i,i)$$
(17)

From second derivative of variable $\theta_i(z_i)$, we obtain:

$$\theta_i''(1)\approx\theta_j''(1)$$
(18)

After calculating (15), (17) and (18):

$$g_i(i,i)=\frac{\lambda_i^2}{\sum\frac{\rho_k}{1-\rho_k}}[\sum\frac{\beta_k}{\lambda_k(1-\rho_k)}g_k(k,k)-\theta\sum\frac{\beta_kA_i''(1)}{\lambda_k(1-\rho_k)}]$$
(19)

By calculating (15) and (19), the approximated expression of $g_i(i,i)$ is obtained, The average waiting time is obtained by substituting $g_i(i,i)$ into the the following equation:

$$E(w_i)=\frac{g_i(i,i)}{2\lambda_i g_i(i)}-\frac{(1-2\rho_i)A_i^*(1)}{2\lambda_i^2(1-\rho_i)}+\frac{\lambda_i B_i^*(1)}{2(1-\rho_i)}=\frac{1}{2(1-\rho_i)\sum\gamma_k\sum\frac{\rho_k}{1-\rho_k}}$$

$$\{\sum\rho_k\sum R_k^*(1)+\sum\rho_k[(\sum\gamma_k)^2-\sum\gamma_k^2]+\theta\{\sum\rho_k\sum\frac{\lambda_k B_k^*(1)}{1-\rho_k}+$$

$$\sum\gamma_k[(\sum\rho_k)^2-\sum\rho_k^2]+\sum\rho_k-(1-\sum\rho_k)\frac{\rho_k}{1-\rho_k}-(1-\sum\rho_k)$$

$$\sum\frac{\beta_k A_k^*(1)}{\lambda_k(1-\sum\rho_k)}\}\}-\frac{(1-2\rho_i)A_i^*(1)}{2\lambda_i^2(1-\rho_i)}+\frac{\lambda_i B_i^*(1)}{2(1-\rho_i)}$$

(20)

IV. SIMULATION EXPERIMENT

According to the asymmetric polling system model established above, simulation experiments were carried out under the premise of system stability of $\sum_{i=1}^{N}\lambda_i\beta_i=\sum_{i=1}^{N}\rho_i<1$. Simulation experiments were was completed in the MATLAB2014a platform .The service times of all packets are exponentially distributed with mean β_i in queue i .The arrival process are Poisson process with arrive rate λ_i in queue i.The switch-over time are independent of each other with γ_i in queue i. The simulation parameters are marked below the Figure.

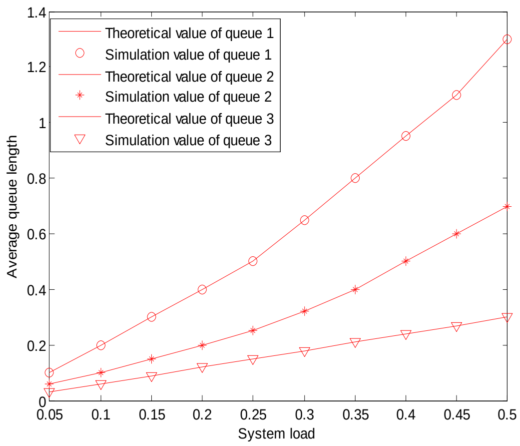

Figure 2: Relationship Between Average Queue Length and System Load

($\beta_i=1,\gamma_i=1,N=3,\lambda_1:\lambda_2:\lambda_3=1:3:6,i=1,2,3$)

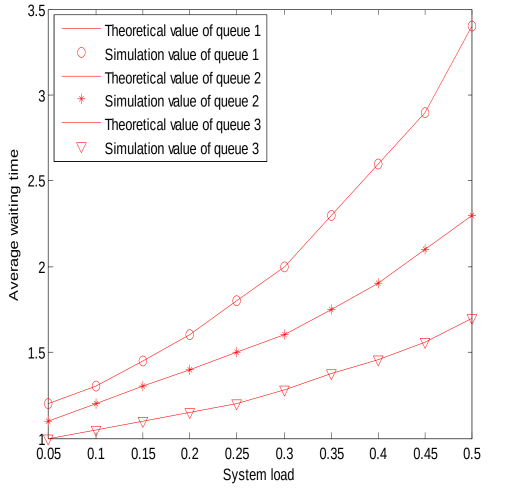

Figure 3: Relationship Between Average Waiting Time and System Load

($\beta_i=1,\gamma_i=1,N=3,\lambda_1:\lambda_2:\lambda_3=1:3:6,i=1,2,3$)

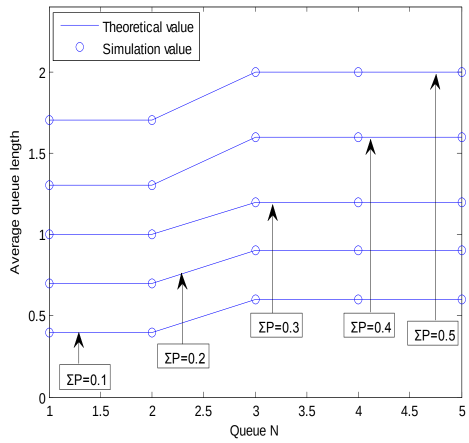

Figure 4: Relationship Between Average Queue Length and System Load ($N=5,\sum\rho=\sum_{i=1}^{N}\lambda_i\beta_i$)

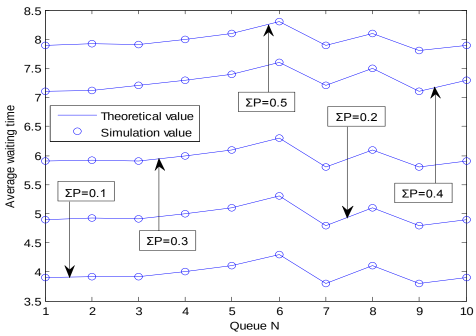

Figure 5: Relationship Between Average Waiting Time and System Load ($N=10,\sum\rho=\sum_{i=1}^{N}\lambda_i\beta_i$)

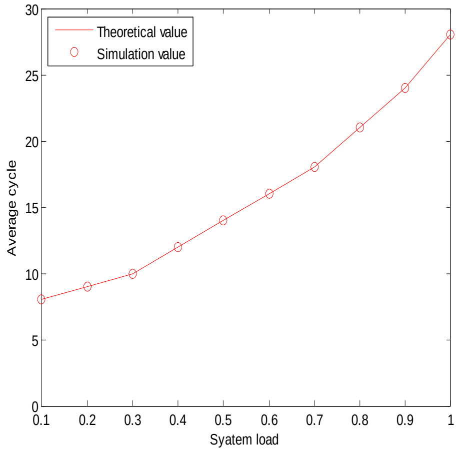

Figure 6: Relationship Between Average Cycle and System Load ($N=5, \beta_i=1, \lambda_i=\{0.02:0.01:0.2\}$ **)**

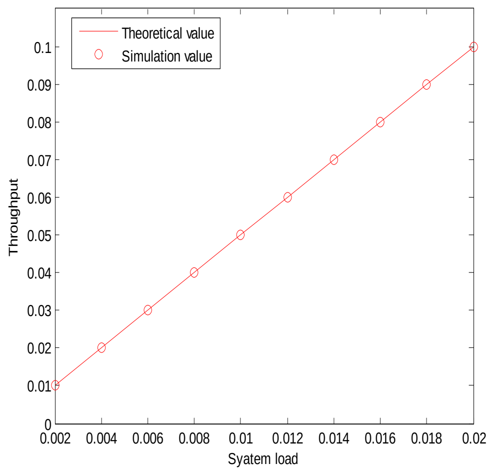

Figure 7: Relationship Between Throughput and System Load ($N=5, \beta_i=1, \lambda_i=\{0.02:0.01:0.16\}$)

4.1 Analysis of Simulation Results

First, from Fig. 2 to Fig. 7, we can see that the theoretical values and simulation values have smaller errors and are approximately equal, this shows that the theoretical analysis are correct and reasonable.

Fig. 2 describes the relationship between the average queue length and system load, it can be seen that the average queue length increases with increase of system load,and due to the different arrival rates λ_i of each queue, the average queue length of each queue is also different.

Fig. 3 describes the relationship between the average waiting time and system load, it also can be seen that the average waiting time increases reasonably with increase of system load,and due to the different arrival rates λ_i of each queue, the average waiting time of each queue is also different, it's consistent with the theoretical derivation.

As you can see from Fig. 4 and Fig.5, the average queue length and the average waiting time are non-linear, this is due to the asymmetric system with different parameter settings, it shows that this system is more suitable for multi-service system's multi-access.

Fig.6 describes the relationship between the average cycle and system load, it also can be seen that the average cycle increases reasonably with increase of system load,and the error between theoretical values and simulation values are small.

Fig. 7 describes the relationship between the throughput and system load, it also can be seen that the throughput increases reasonably with increase of system load.But, Fig. 2 and Fig. 3 also show that the average queue length and average waiting time of the system increase reasonably with increase of system load,however, the throughput increases reasonably with increase of system load,Therefore, the average queue length or average wait time should be taken as a constraint condition to increase the system throughput.

V. CONCLUSION

Intelligent distribution network communication services are far more complex than traditional distribution networks, especially the application of new protection technologies based on network communication, which puts higher requirements on the service quality and real-time performance of communication services. In view of the shortcomings of the existing EPON system bandwidth allocation method, this paper proposes an asymmetric full service polling control system. The arrival time of the information packets entering the queue at any time, the query conversion time between the service time and the queue are random. Variable. Using the Markov chain [11] combined with the probabilistic parent function, the derivation process of the performance characteristic analysis is given in detail, and the method of approximate equalization of the cyclic query period is used to give a reasonable average waiting time. Analytical method, the simulated simulation value is approximately equal to the theoretical value. The system model dynamically allocates the bandwidth of each service to meet the application requirements of different communication services, especially relay protection and high real-time communication services. The model meets all types of business needs, as well as multi-channel multiple access technology. The method can effectively improve the communication efficiency, and the communication requirement of the low priority service is taken into consideration on the basis of ensuring the real-time performance of the high priority service.

The simulation results show that compared with the traditional method, the dynamic bandwidth allocation method of EPON system in this paper has obvious improvement in bandwidth utilization and real-time response capability to priority services, which can better meet the communication of smart distribution network. Business, especially the application requirements of relay protection for high real-time communication services.

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