Innovative Design and Intelligent Manufacturing
L.C. Jain et al. (Eds.)

doi:10.3233/FAIA241094

A Study on the Application Program of Electric Power Information System Based on Quantum Communication

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Abstract. This research proposes a scheme of power information system based on quantum communication, aiming at improving the reliability and security of power service transmission. The new algorithm LD-WFQ (improved weighted fair queue) prioritizes the data packets that are about to timeout by estimating the expected time consumption of the data packets to be encrypted, so as to reduce the quantum encryption timeout rate of low priority services. The experimental results show that the LD-WFQ algorithm does not affect the performance of high priority services while reducing the ratio of overtime data packets, and shows good optimization effects under different key request rates. Compared with the traditional WFQ algorithm, the LD-WFQ algorithm has obvious advantages in meeting the requirements of power business encryption and improving the utilization rate of quantum keys, and has practical application significance.

Keywords. Power system quantum communication; quantum key distribution; queue scheduling

1. Introduction

Quantum cryptography is a revolutionary technology in the field of information security, which has the unique security of unconditional security and unmeasurable security, i.e., in principle, even if the attacker has unlimited computational resources, it cannot be deciphered and eavesdropped on the quantum cryptography, and it can fundamentally guarantee the information security [1]. For the national economy and people’s livelihood of the power dedicated communication network, timely development of a new generation of confidential communication technology based on quantum communication technology absorption and industrialization research, quantum cryptography applied to the existing power system network of the State Grid, can improve the power information system’s ability to prevent attacks, to achieve safe operation. In the existing scheduling network of power system, adding quantum cryptographic communication technology, carrying out quantum cryptographic application test and verification, its success can be used as a new generation of power system information network development, promotion and application of the foundation and model, for the State Grid electric power system information security protection construction to lay the foundation, but also on the

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information security of the power system defense technology of a major breakthrough [2].

Power Dispatching Data Network (PDDN) is an important part of large interconnected power grid and the basis for realizing power grid dispatching automation [3]. With the continuous development of ubiquitous power Internet of Things, the scale of PDDN continues to expand, and the number of businesses it carries continues to increase, making the role of information communication technology in power system dispatching more prominent. In order to improve the intelligence and informatization of the power grid, the information security of information and communication technology, which plays an important role as a bridge, deserves full attention and great attention [4].

2. Literature Review

Throughout the current research on power system information security at home and abroad, it mainly focuses on the production control system in Zone I and Zone II. Sidhu, J. S. and others proposed an advanced hybrid key management architecture for SCADA system [5]. Pittaluga, M. and others designed a security scheme based on SM2 algorithm for intelligent substation system [6]. Cohen, A. et al. proposed a key agreement method including a key management center for embedded devices such as smart meters [7]. Gupta, B. B. and others designed a security platform based on SM2 algorithm for power secondary system [8]. It can be seen from the above introduction that the security problems of the power dispatching system at this stage have attracted extensive attention at home and abroad, and its security measures have been relatively mature in the classic security system. However, with the rise of the ubiquitous concept of the power Internet of Things, the amount of data in the power grid is growing rapidly, and the number of key bits required and the amount of encryption and decryption calculations are also growing. With the continuous development of quantum computing, the originally thought unsolvable computing problems are also gradually cracked. The current classic security system has been unable to meet the needs of the power system, and new security measures need to be taken to meet the overall information security needs under the new situation. Wang, C. and others introduced a six node QKD MAN built by different quantum key distribution (QKD) systems with the help of trusted relays [9]. Manzalini, A. and others introduced a 5-node wavelength saving QKD MAN based on commercial telecommunication links [10]. Akhtar, M. W. and others introduced a 7-node QKD hierarchical MAN based on WDM router, trusted relay and optical switch [11].

In this paper, the WFQ algorithm is improved, and a low delay weighted fair queuing (LD-WFQ) algorithm applied to power system quantum encryption service is proposed. On the premise of meeting the delay requirements of each queue as far as possible, the scheduling order is adjusted, the delay of each queue is balanced, and the delay reaching rate is improved.

3. The Research Methodology

3.1. Queue Scheduling Model

Some of the power service transmission requirements and the safety zones to which they belong are shown in Table 1.

Table 1. Research records.

Electricity business	latency requirements	BER requirements	The security zone
Wide Area Proxy Services	100ms	10^{-6}	I
Wide-area measurements	30ms	10^{-9}	I
Dispatch calls	150ms	10^{-3}	I
Dispatch automation	100ms	10^{-6}	I
The stabilization system	30ms	10^{-7}	I
protection information management	15min	10^{-5}	II
Electricity metering telemetry	Seconds	10^{-6}	II

Since the service routing in the power communication network is manually configured and will not change dynamically, the forwarding delay requirements of each service at a node can be calculated according to the route hops and the end-to-end delay requirements of the service. The queue scheduling system consists of multiple queues, each of which is a first in first out (FIFO) queue, and each queue has different scheduling priorities (weights). The scheduler schedules the queue according to the queue scheduling algorithm to determine the queue that should perform the outbound operation currently. Queue is allocated to different services according to their forwarding delay requirements at a node, and the forwarding delay requires that the same services enter the same queue when queuing.

The rate of quantum key generation , the r_q and the length of the quantum key required for data packet encryption , L^' determines the number of data packets that can be encrypted per unit of time, and the rate at which the data packets are encrypted and sent over the classical channel r_c and the size of the data grouping itself , the L The number of data packets that can be sent per unit of time is determined by the number of data packets that can be sent per unit of time. Thus, the quantum communication queue scheduling system is established, as shown in Fig. 1.

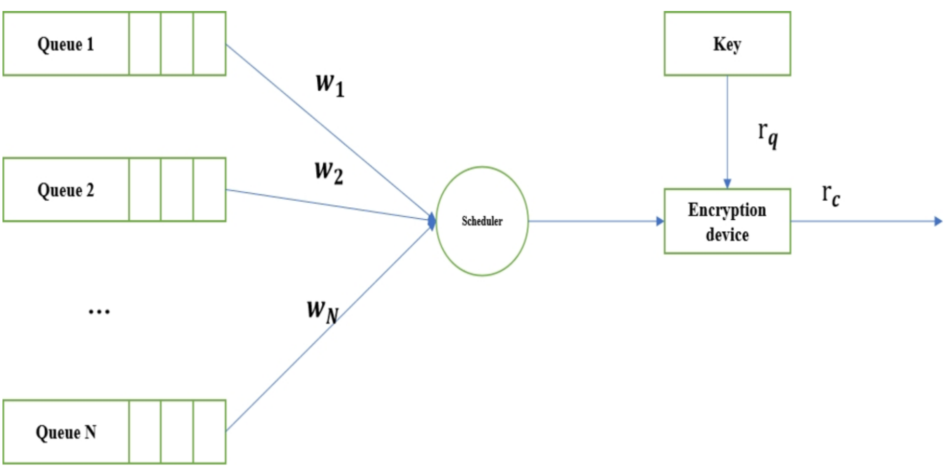

Figure 1. Quantum communication queue scheduling system model.

Among them.N is the number of queues, the weights of each queue are When the data packet to be encrypted is queued and finally selected out of the queue, it is considered that the scheduler responds to the request for encryption of the data packet at this time. When the data packet to be encrypted is queued and finally selected out of the queue, it is considered that the scheduler responds to the encryption request of the data packet at this time, and the specified length of the quantum key generated will be used to encrypt the data packet. In order to ensure the security of the quantum key, the key is not stored, and the key needed for encryption is generated instantly.

Different from the traditional communication network business, electric power business is more sensitive to the delay, the traditional communication network business delay is often only reduce the user experience, while the key business timeout in the electric power communication network will lead to failure, and may bring certain security risks, so this paper uses the delay as a parameter to calculate the queue weights, so that the business with higher delay requirements get more scheduling opportunities. Due to the large difference between the delay requirements of different power services, the use of linear function to calculate the weight will make the weight difference is too large, resulting in the lower delay requirements of the business is almost no scheduling opportunities, the fairness between the business cannot be guaranteed, so this paper according to the formula (1) to calculate the queue weight:

$$w_i = \frac{1/\lg T_i}{\sum_{j=1}^{N} 1/\lg T_j}, i = 1, 2, \cdots, N \tag{1}$$

Among them. For each queue corresponding to the service forwarding delay requirements, the larger the weight value indicates that the queue in the scheduling system, the higher the priority.

3.2. Queue Scheduling Algorithm

tIn this paper, the basic idea of WFQ algorithm is applied to the quantum communication queue model of power system. In view of the fact that WFQ algorithm cannot directly control and optimize the delay to ensure the delay of high priority queues, and the composite algorithm combined with SP algorithm cannot avoid the “hunger” phenomenon of low priority queues, LD-WFQ algorithm is proposed, This algorithm estimates the expected time consumption of data packets to be encrypted in the encryption system and compares it with its forwarding delay requirements. It prioritizes the data packets to be encrypted that are about to meet the forwarding delay requirements. By adjusting the scheduling order, it balances the delay of each queue and improves the delay compliance rate of services.

In order to facilitate the calculation of the expected time consumption, when the data group enters the queue, it no longer calculates its virtual arrival time and virtual departure time, but only adds a timestamp to record the time of its arrival in the queue α_i^k The calculation of the virtual arrival time and virtual departure time is performed when the data packet arrives at the head of the queue. At this time, the scheduler calculates and stores the virtual arrival time and virtual departure time of the data packet at the head of each queue in the queue, which is written as and , as follows (2) (3).

$$S_i = \max\left\{F_i^-, V\left(a_i^k\right)\right\} \tag{2}$$

$$F_i = S_i + \frac{L_i}{w_i} \tag{3}$$

Among them. F_i^- denotes the queue , and i The virtual departure time of the last data packet, its initial value is 0.

LD-WFQ algorithm estimates the forwarding delay of the data packets at the head of each queue in the queue scheduling system, schedules the data packets to be encrypted that will exceed the forwarding delay and have high priority, and satisfies the forwarding delay requirements of the data packets to be timed out first by adjusting the sending order of the data packets to be encrypted and balancing the delay of each queue, It effectively reduces the overtime data packet ratio, so that quantum encryption can be performed more efficiently.

4. Analysis of Results

Based on Matlab 2014a simulation platform, this paper selects four queues for simulation analysis, and assumes that the forwarding delay requirements of each queue are T1=100 ms, T2=20 ms, T3=300 ms, and T4=40 ms respectively; The length of key required for data packet encryption to be encrypted is L^'=128 bit; The quantum key generation rate R=1 Mbit/s, the arrival of data packets to be encrypted in each queue conforms to the Poisson distribution and the arrival rate is the same, and the sum of the four queue key request rates is 1 Mbit/s. In general, the time delay caused by data packets sent through traditional channels is far less than its forwarding delay requirements, so this part of delay is ignored in the simulation.

In order to investigate the optimization ability of the algorithm on timeout rate under different data packet arrival rates, the simulation analysis of the algorithm is carried out by constantly changing the data packet arrival rate, and in order to reduce the error caused by the high randomness of the queue scheduling system, the average of the results of 30 times is taken, as shown in Fig. 2. In order to visualize the effect of the algorithm and reflect the relationship between the key request rate and the quantum key generation rate, the horizontal coordinate in Fig. 2 is the key request rate.

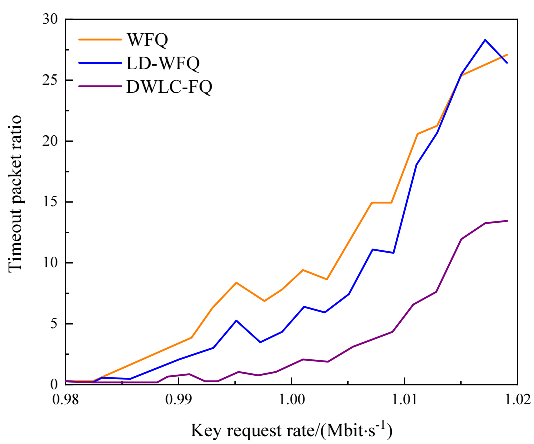

Figure 2. Ratio of total timeout data grouping in the scheduling system

Because queue 2 has more opportunities to get scheduled and put in, only a few data packets have timed out, so the average results of its 30 simulations are still highly random, and the ratio curve of overtime data packets of other queues is more flat. Although DWLC-FQ algorithm can better balance the delay of each queue, it fails to directly limit and optimize the forwarding delay. Although it can reduce the timeout data packet ratio by balancing the delay, the optimization effect is not outstanding, and the algorithm performance is poor when the key request rate is high.

After scheduling with this paper's algorithm, when the key request rate is less than the quantum key generation rate, the timeout data packets are less, and this paper's algorithm can effectively reduce the timeout ratio and keep the timeout ratio at a lower level; when the key request rate is greater than the quantum key generation rate, the queue scheduling system is likely to be in a congested state, of which, queue 3 and queue 4 are seriously congested, and this paper's algorithm can effectively reduce the timeout ratio without causing any significant negative impact on the high priority queues, and based on this, effectively meet the delay requirements of data packet forwarding in queue 3 and queue 4, and does not cause any significant negative impact on the high priority queues. The algorithm in this paper can adjust the scheduling order to meet the packet forwarding delay requirements of queue 3 and 4 as much as possible, and at the same time, it does not have any obvious negative impact on the timeout ratio of the high-priority queue, and on the basis of which, it effectively reduces the rate of timeout packets. Simulation results show that this paper's algorithm can effectively reduce the timeout ratio of the encrypted data packets although the balancing effect of the delay of the encrypted data packets in each queue is general, and can achieve better optimization effect under different key request rates. The algorithm in this paper increases the delay controllably within the allowed range of delay in exchange for a higher delay compliance rate, which can better meet the encryption demand of electric power business and improve the effective utilization rate of quantum key, and is of more practical significance.

5. Conclusion

When quantum encryption technology is applied to power communication systems, it can only meet the needs of some important power services due to the low coding rate of quantum keys. Therefore, scheduling algorithms are needed to allocate quantum encryption bandwidth. In this paper, a queue scheduling model for quantum communication key distribution in power system is proposed, and the basic idea of WFQ algorithm is applied to the model. A queue scheduling algorithm for optimizing the delay of quantum encryption service in power system, namely LD-WFQ algorithm, is proposed. By estimating the expected time consumption of data packets to be encrypted, priority is given to scheduling data packets to be encrypted that are about to timeout, Reduce the timeout rate of data packets to be encrypted, and will not cause a significant deterioration of the timeout rate of data packets to be encrypted in high priority queues. Under the condition of a certain coding rate, the LD-WFQ algorithm can better meet the delay requirements of the services to be encrypted, effectively encrypt more data packets to be encrypted, improve the effective utilization rate of the quantum key, which also alleviates the problem of low coding rate of the quantum key to a certain extent. The simulation results show that the LD-WFQ algorithm can effectively reduce the quantum encryption timeout rate of low priority services, improve the encryption efficiency, better meet the encryption requirements of power services, and have more superior performance on the basis of maintaining the delay compliance rate of high priority services.

Funding

This reserach was funded by Southern Power Grid Corporation Technology Project, grant number 066500KK52222057

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