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Research Article

A Packet Scheduling Method Based on Dynamic Adjustment of Service Priority for Electric Power Wireless Communication Network

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With the development of the energy Internet, power communication services are heterogeneous, and different power communication services have different business priorities. The power communication services with different priorities have different requirements for network bandwidth and real-time performance. For traditional unified service, a scheduling method cannot meet these service requirements at the same time, and electric power communication network cannot guarantee the quality of service. Therefore, how to make full use of the time-varying characteristics of communication resources to meet the business needs of different priorities and achieve the goals of high resource utilization and transmission quality has become one of the urgent problems in the power communication network. For this reason, in order to adapt to the real-time congestion of the network, we have designed a packet scheduling method based on the dynamic adjustment of service priority, which dynamically adjusts the priority of the power service on the node; in addition, an evaluation method for the trust value of wireless forwarding nodes is introduced to improve the security of data transmission; and finally, we valuate the channel quality to establish a reasonable and efficient packet scheduling mechanism for services of different priorities. Simulation results show that this method improves the communication performance of high-priority services and improves the spectrum resource utilization of the entire system.

1. Introduction

With the development of energy Internet, based on the traditional power communication facilities, a large number of mobile heterogeneous terminal nodes are distributed on the edge of the network, forming a mobile self-organizing network. Mobile ad hoc network is a kind of distributed wireless ad hoc network. Data packets are transmitted in the way of multihop forwarding in the connected links of the network. With flexible architecture, it is used to carry power communication network services, which has become a trend in the future.

Due to the continuous development of intelligent power distribution network and the increase of distribution and consumption communication service types and traffic, the existing wireless network resources cannot adapt to the large-scale deployment of smart grid. The QoS indicators of power communication services include data rate, delay, and packet loss rate. By ensuring transmission bandwidth and reducing transmission delay, packet loss rate, and delay jitter, the quality of service can be improved. Compared with the general communication network, the service of power communication network is more heterogeneous, and the quality of service (QoS) requirements of different services are also very different. Control service has high requirements for delay and reliability [1–4]. For example, distribution automation and distributed power control services need to have channel protection and communication load control functions, so it is necessary to establish low delay and high data rate communication between substation and intelligent power equipment; power information collection service of users does not require high real-time performance and transmission rate [5, 6], but the communication volume is large, and the information security requirements are high.

Smart grid introduces the concept of dynamic adjustment of service priority to solve the problems of spectrum resource shortage and low spectrum utilization rate faced by smart grid [7–9]. For power communication service priority adjustment, the existing methods cannot dynamically adjust the priority level of data packets according to the real-time congestion state of the network; for the scheduling of service packets, the traditional scheduling mechanism lacks consideration of channel resource changes and cannot provide reliable quality assurance for low-priority services under the condition of real-time changes of available channel transmission resources [10, 11]. Therefore, the improved routing algorithms include on-demand QoS routing algorithm, QoS routing algorithm based on fuzzy control, and opportunistic scheduling algorithm with packet delay guarantee [12]. In addition, most of the existing packet scheduling mechanisms only consider the absolute priority of high-priority services, ignoring the relative priority of other services, which cannot meet the requirements of providing differentiated QoS services for heterogeneous services in the intelligent power communication network.

Therefore, how to use efficient service scheduling algorithm to make full use of the time-varying characteristics of communication resources, to support the future intelligent distribution and utilization of power communication edge data transmission, and to meet the requirements of high resource utilization and transmission quality, has become one of the problems to be solved urgently in power communication network. Therefore, this paper studies a dynamic priority-based power wireless communication service packet scheduling mechanism to adapt to the operation requirements of the future intelligent power distribution and utilization communication network.

The main contributions of this article are as follows:

(1) According to the communication requirements and service characteristics of the intelligent power distribution and utilization wireless communication network, in consideration of the service QoS requirements and importance, we design a complete dynamic adjustment algorithm of power wireless communication service packet priority to adapt to the different states in the network operation and ensure the quality of service

Based on the dynamic adjustment algorithm of power wireless communication service packet priority, we comprehensively consider the real-time change of network transmission resources; then, an evaluation method for the trust value of wireless forwarding nodes is introduced to improve the security of data transmission; and finally, we valuate the channel quality to establish a reasonable and efficient packet scheduling mechanism for services of different priorities, ensure the QoS requirements of various services, and optimize the system utilization rate.

(2) The reminder of this article is organized as follows. In Section 4, the system model is proposed, and the packet scheduling mechanism of power communication service based on dynamic priority is discussed in Section 5. Simulation process is given and discussed in Section 6. Finally, we conclude this paper in Section 7

2. Related Work

At present, most researches on service routing are in-depth research on the above-mentioned key technologies including node mobility model, message forwarding mechanism, and congestion control mechanism. This section will introduce the following two mainstream routing algorithms and the latest research on mainstream algorithms.

2.1. Routing Based on Delivery Probability. Lindgren et al. proposed a routing strategy based on delivery probability [13, 14], namely, PRoPHET routing. The node records its own historical information, and when the nodes meet, they share each other's historical information and transfer information. Use this information to evaluate network information, thereby predicting the contact probability of a node to other nodes. Suppose that node S holds a message and its destination node is D. When node S encounters node B, if the probability of contact between node B and node D is greater, the router thinks that node B is more likely to deliver message m to node C. Node A copies and forwards the message to node B; otherwise, node S does not forward it. That is, in this routing mechanism, the transmission of service is more inclined and will be delivered to nodes that have greater contact with the destination node. Among them, the calculation of contact probability mainly has two parameters: one is the attenuation weight γ, and the other is the transfer weight β. The contact probability of two frequently connected nodes is updated and increased each time they meet. When two nodes do not meet within a certain time interval, the contact probability between the two nodes becomes smaller under the effect of the attenuation weight. If node S is in contact with node B, node B is in contact with node D, but node S is not in contact with node D, and the existence of the transfer weight will bring the probability of contact between S and D to a certain value. Although the PRoPHET method selects the node of the infected message, its copy amount in the network is still unlimited, and it is still easy to cause network congestion and cause network performance deterioration. For the vehicle opportunity network [15, 16], Du et al. combined the message transfer strategy of the PRoPHET protocol with the message replication control strategy of the jet waiting protocol, which effectively controlled the number of replications, thereby reducing the overhead. Bai et al. proposed a

Bayesian network-based method to estimate the contact probability between network nodes, which improves the accuracy of the contact probability estimation, thereby improving the performance of routing.

2.2. Routing Based on Different Business Requirements. The definition of business distinction can be divided into two types, one is the distinction of the same type of business due to different contents, such as the priority of rescue information when a disaster occurs. The other is business differentiation caused by different business types, such as text, picture, or video services.

Mashhad and Capra considered a general model for measuring the priority of messages [17] and modeled user's interest in messages in two ways: users can define the objects they are interested in (people-centered) or the content of interest (in content as the center). Regarding service differentiation caused by different service types, different types of services have different QoS requirements such as bandwidth, packet loss rate, and delay. The research focuses on the QoS guarantee of different services. Although the network provides three different QoS classes: accelerated, normal, and batch, to distinguish messages, if you simply prioritize messages based on their QoS class, applications that belong to the lower class will not be able to get it. To the transmission opportunity. Some research focuses on how to solve the sorting problem between different classes. Tajima et al. defined the data arrival rate as the data arrival rate of all data that reached the target node [18] and the rate of all data that was deleted due to timeout but did not reach the target node. It is called the data loss rate. Determine the data discarded by the node when the data in the buffer is full, estimate the data loss rate and data arrival rate of the entire network, and modify the buffer partition ratio according to the deletion rate of the priority category [19–21]. Xu et al. proposed the concept of reference probability. The meeting node defines different reference probabilities for different data packet priorities. If the reference probability of the meeting node is greater than the forwarding probability of the sending node, the data packet is forwarded; otherwise, it is not forwarded [22–24]. But these strategies do not adapt to the dynamic changes of the network. If resources are insufficient to meet all constraints, the strategy will still allocate resources proportionally and may not meet any category of requirements or even the highest priority requirements. On the other hand, if resources are sufficient, it may unnecessarily continue to favor higher-level classes, restricting lower-level classes to achieve high performance. Considering the above problems, Matzakos et al. proposed a routing algorithm to adapt to resource allocation in a dynamic environment [25–27] and defined constraints to optimize network-wide performance while satisfying the QoS constraints of a single category, but the contagion strategy it uses consumes a large resource consumption, and scheduling information needs to be provided globally [28, 29], which is not suitable for the actual application of delay-tolerant networks.

Therefore, the subject researches an opportunistic routing planning algorithm based on business priority in a dynamic network that can use local information.

The above research focuses on the services differentiated by content, and the research focuses on how to differentiate the services and determine their priorities. However, low-priority services may not get transmission opportunities for a long time, which is not always feasible in the actual power communication network. In order to fill this research gap, we focus on the priority dynamic adjustment algorithm for power communication services and propose a dynamic scheduling mechanism for service data packets to solve complex service routing problems.

3. System Model

In the intelligent distribution communication network involved in this chapter, the elements that need to be investigated include the services with different priorities in the network, network spectrum resources, and the network behavior (channel access, backoff, and handover).

3.1. Service Description Model. In the network, each service will have a service description model to describe its constraint information and application attribute information, as shown in Figure 1.

(1) Type: basic description of service, such as voice, text, picture, and important notice

(2) Size: for the description of service size, too large service description will cause the increase of network transmission cost, such as occupying too much cache space and occupying longer transmission time

(3) DelayGoal: if the current network can support the goal of delay, the algorithm will determine the minimum number of copies based on the target delay

(4) LossGoal: if the desired service quality of the service is to be achieved, the goal of packet loss rate of the service needs to be greater than the current network packet loss rate

(5) DalayAccept: if the current network cannot support the target delay of the service, the number of copies will be determined based on the maximum acceptance delay

(6) LossAccept: the target packet loss rate and maximum accepted packet loss rate, the target delay, and the maximum accepted delay form the service quality range of the service. If the network cannot support the demand for service quality, the service request can be rejected

(7) PriLevel: this indicates that the user wants the service level provided by the network. There are three priority levels: H, M, and L

(8) DownFlag: accepting the downgrade sign indicates that a certain quality of service can be downgraded when the network is congested

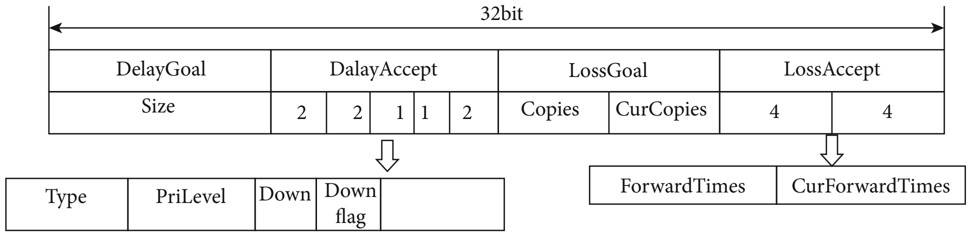

Figure 1: Service description model.

(9) Down: when the network is in congestion, it is set to 1 to indicate that the service is downgraded. When the network is in a good state, down is set to 0

(10) Copies: the maximum number of copies of service description. The more the copies of service description, the larger the buffer space occupied, and the more the network resources required. So we need to preallocate the number of copies of service description

(11) CurCopys: it represents the number of copies of the service description owned by the current node

(12) CurForwardTimes: the number of times the service description was forwarded during the wait step

(13) ForwardTimes: the number of times the service description can be forwarded during the wait step

3.2. The Specific Priority of Service. Electric power communication network services can be divided into production control area services and management information area services according to their categories. The specific priority of service is shown in Table 1.

3.3. Network Spectrum Resources. The resource of cognitive wireless network is network spectrum resource. Since each service is assigned an authorized channel, the channel set can be represented as $\mathbf{F} = \{F_1, F_2, \cdots F_M\}$.

3.4. Network Behavior. Each service uses idle spectrum resources for data transmission. However, if high-priority service reappears during low-priority service information transmission, low-priority service should be immediately discarded from the channel or switched to other channels to continue transmission. Therefore, low-priority service's network connectivity is affected by high-priority service's behavior, and its services are often in the state of interruption or switching. The spectrum of low-priority service available links is different and dynamic due to the activity of high-priority service.

4. Algorithm Design

4.1. Service Priority Dynamic Adjustment Strategy. In order to maximize the delivery rate, this section mainly solves two problems related to spray wait routing algorithm.

(1) When multiple messages coexist in the local buffer and the node is unable to determine whether the node and the meeting node will forward all messages long enough, it should decide which message to send first

(2) If a new message arrives at the node's buffer and overflows, a drop decision should be made between messages, that is, which message to discard

In order to solve the above two problems, we set a priority for messages in the internal queue of the node to determine the ordering and discarding of messages. The queue priority of messages in a node is a complex function of the number of message copies, the remaining number, and the priority of the message itself [17].

$$\text{Priority}_i = \Delta P = f(\text{TTL}_i, C_i, W_i). \tag{1}$$

Table 2 shows the parameters and explanations involved in this section.

The meeting time of a node with other $N-1$ nodes in the network is I_i, $\quad i \in \{1, 2, 3, \cdots, N\text{-}1\}$. The encounter time satisfies the exponential distribution, and the parameter is λ_e [30]. Therefore, the minimum encounter time is $\boldsymbol{I}_{\min} = \min_{\boldsymbol{i} \in \{1,2,3,\cdots,\boldsymbol{N}-1\}}$,

$$\lambda_{\min} = \frac{1}{E(I_{\min})} = \frac{N\text{-}1}{E(I)}. \tag{2}$$

The calculation [30] of $P(i)$ is shown in formula (3). The delivery probability of message i is composed of the probability $P(T_i)$ that message i has been delivered and the probability $P(RT_i)$ that message i will be delivered within the remaining time RT_i.

$$\boldsymbol{P}(\boldsymbol{i}) = \boldsymbol{P}(\boldsymbol{T_i}) + (\boldsymbol{1} - \boldsymbol{P}(\boldsymbol{T_i}))\boldsymbol{P}(RT_{\boldsymbol{i}}). \tag{3}$$

Assume that the number of nodes that receive message i be $m_i(T_i)$ and the number of nodes currently holding the message i be $n_i(T_i)$; the probability$P(T_i)$that message$i$has been delivered is:

$$\boldsymbol{P}(\boldsymbol{T_i}) = \frac{\boldsymbol{m_i}(\boldsymbol{T_i})}{\boldsymbol{N} - 1}, \tag{4}$$

where 1-$P(RT_i)$ means that the message i is delivered not only in T_i but also in the remaining time $RT(\text{TTL}_i - T_i)$

Table 1: Electric power wireless communication business priority.

Power communication network services division		Specific services	Services priority
Production control area services	Control area services	Energy management system (EMS), relay protection system, security automatic control system, etc.	First-level services
		Emergency power demand response system	Second-level services
	Noncontrol area services	Electric energy metering system, relay protection and fault recording information management system, etc.	Third-level services
Management information area services		Management information system (MIS), office automation system (OA), customer service system, etc.	Fourth-level services

Table 2: Network parameters.

Symbol	Description
$DN(t)$	Total number of messages in the network (excluding copies)
C	Maximum number of copies of a message
C_i	Number of copies of message i on the node
U_i	Priority of message i on the node
W_i	Service priority weight for message i
W_d	Service priority weight
I	Time when a node meets another node in the network, following an exponential distribution $f(x) = \lambda_e e^{-\lambda_e x}$
$E(I)$	Expectation of meeting time
λ_e	Exponential distribution parameter for meeting time ($\lambda_e = 1/E(I)$)

probability that will pass. Assume that RT_i is long enough to spray all copies. The C_i copy of message i will continue to be transmitted to the $\log_2 \boldsymbol{C_i}$ node until the number of copies is reduced to 1. In addition, the interval between adjacent infections can be estimated as $E(I_{\min})$. Every $E(I_{\min})$ time unit, one node will receive the message. W_i is the initial business priority weight of the message i, and W_d is the downgrade weight. (RT_i) can be expressed as follows:

$$\begin{aligned} P(RT_i) &= 1 - \prod_{k=0}^{\log_2 C_i} e^{-\lambda_e n_i(T_i)[W_i W_d RT_i - kE(I_{\min})]} \\ &= 1 - e^{-\lambda_e n_i(T_i)[(\log_2 C_i + 1) W_i W_d RT_i - (1/(2(N-1)\lambda_e)) \log_2 C_i(\log_2 C_i + 1)]}. \end{aligned} \tag{5}$$

Combine the above formulas:

$$\begin{aligned} P(i) = {} & \frac{m_i(T_i)}{N-1} + \left(1 - \frac{m_i(T_i)}{N-1}\right) \\ & \cdot \left(1 - e^{-\lambda_e n_i(T_i)[\log_2 C_i + 1] W_i W_d RT_i - (1/(2(N-1)\lambda_e)) \log_2 C_i(\log_2 C_i + 1)}\right). \end{aligned} \tag{6}$$

Global success rate P is calculated as

$$P = \sum_{i=1}^{k(t)} P(i). \tag{7}$$

Derivative is calculated as

$$\Delta P = \sum_{i=1}^{k(t)} \left[\frac{\vartheta P}{\vartheta n_i(T_i)} \Delta n_i(T_i)\right]. \tag{8}$$

The priority adjustment queue proposed in this section is to maximize the delivery rate. When nodes meet, cancel the service i; if the injection is carried out, the number of nodes holding the message in the network will increase, $\Delta n_i(T_i) = 1$; if not, the number of nodes holding the message will increase. If there is injection, the number of nodes holding the message does not change, $\Delta n_i(T_i) = 1$. The priority adjustment queue proposed in this section is to maximize the delivery rate. The priority of message i is exactly the derivative of the delivery rate P.

$$\begin{aligned} U_i = {} & \left(1 - \frac{m_i(T_i)}{N-1}\right) \lambda_e \\ & \cdot \left[(\log_2 C_i + 1) W_i W_d RT_i - \frac{1}{2(N-1)\lambda_e} \log_2 C_i(\log_2 C_i + 1)\right] \\ & \times e^{-\lambda_e n_i(T_i)[(\log_2 C_i + 1) W_i W_d RT_i - (1/(2(N-1)\lambda)) \log_2 C_i(\log_2 C_i + 1)]}. \end{aligned} \tag{9}$$

The calculated priority is a composite function of the number of message copies, the remaining TTL, and the service priority of the message itself, which can estimate the message more accurately. In most cases, the large number of remaining copies of messages and the remaining TTL indicate that the scope of message infection is small, and these messages should have higher priority.

Each node can calculate the priority of messages in the buffer. Therefore, the node can schedule the sending order and make the discard decision according to the priority. Each node manages its buffer in a distributed way, which means that each node only cares about the priority in its own buffer. When two nodes meet, they only consider which message to send between messages in the buffer and which message to delete when the overflow occurs.

In formula (10), $m_i(T_i)$ is the number of nodes that receive message i; $n_i(T_i)$ is the number of nodes currently holding the message now. Assume that $d_i(T_i)$ is the number of nodes that have discarded the message:

$$n_i(T_i) = m_i(T_i) + 1\text{-}d_i(T_i). \tag{10}$$

In order to accurately estimate $d_i(T_i)$, each node maintains one piece of information of the discard history, including node ID, list of discarded messages, and record collection time.

Assume that the size of the above data structure is negligible compared to the size of the message. The discard queue contains all discarded message ID, and the record time is the generation time of the record. When nodes meet, they exchange and update their records. Only the source node can modify the record time and only if a new discard occurs in its buffer. When two nodes meet, exchange and update their respective discard history information. After a period of time, each node can estimate $d_i(T_i)$.

The estimation of $m_i(T_i)$ is obtained by the binary characteristic of the binary spray and waiting routing algorithm. The binary spray and waiting routing algorithm is shown in Figure 2. In the whole process, the time when the message is sprayed is recorded, so we can estimate the message transmission process of each node.

The current number of copies of message i is C_i, the initial number of copies is c, and then the height of the tree can be obtained.

$$h = \log_2 \frac{c}{C_i}. \tag{11}$$

Messages are sprayed into a binary tree after a period of time.

$$m_i(T_i) = \sum_{k=1}^{h\text{-}1} 2^{[(t_n\text{-}t_k)/E(I_{\min})]} + 1. \tag{12}$$

4.2. Trust Value of the Node. For secure communication, only nodes with high trust values should be selected for communication. If the computing task is forwarded by a wireless node with a low trust value, the node may take malicious actions, such as discarding data packets. Therefore, every mobile device should interact with a wireless with a high trust value to avoid potential security threats. In order to calculate the trust value of the forwarding node, we introduce the node trust value for evaluation. In this article, we use real numbers between 0 and 1 to evaluate the trust value of cooperative user nodes.

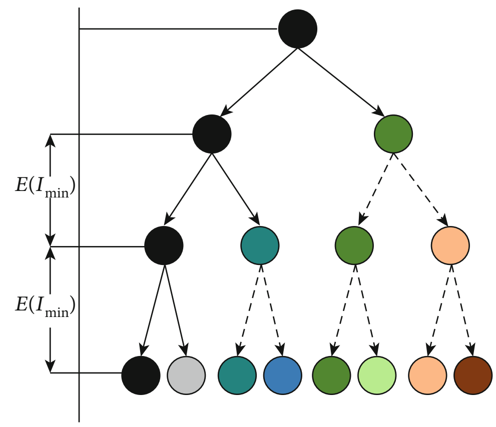

Figure 2: Spraying binary tree process.

Similar to [31], we use node honesty and node capacity to calculate direct trust. Since the mobile communication channel between the mobile device and the forwarding node is unstable and noisy, the communication behavior of the wireless node has considerable uncertainty. We use a subjective logic framework to deal with uncertainty. In the subjective logic framework, the trust value of the mobile device n to the mobile node x_{k_t} can be described as the triple $\omega_{n\to k} = \{b_{n\to k}, d_{n\to k}, v_{n\to k}\}$, where $b_{n\to k}$, $d_{n\to k}$, and $v_{n\to k}$ represent trust, distrust, and uncertainty, respectively. In particular, the relationship between them is determined by the following formula:

$$\begin{aligned} &b_{n\to k}, d_{n\to k}, v_{n\to k} \in [0, 1], \\ &b_{n\to k} + d_{n\to k} + v_{n\to k} = 1. \end{aligned} \tag{13}$$

Based on the trust model of [32], node honesty (NH) can be given by the following formula:

$$\text{NH}_{n\to k} = b_{n\to k} + \xi v_{n\to k}, \tag{14}$$

where $0 \le \xi \le 1$ is a constant representing the degree of influence of trust uncertainty, and

$$\begin{aligned} b_{n\to k} &= (1 - v_{n\to k}) \frac{\alpha_{n\to k}}{\alpha_{n\to k} + \beta_{n\to k}}, \\ d_{n\to k} &= (1 - v_{n\to k}) \frac{\beta_{n\to k}}{\alpha_{n\to k} + \beta_{n\to k}}, \\ v_{n\to k} &= 1 - l_{n\to k}, \end{aligned} \tag{15}$$

where $\alpha_{n\to k}$ and $\beta_{n\to k}$ are the number of successful and failed communications, respectively. $l_{n\to k}$ represents the quality of the communication link, which refers to the probability of packet success. Packet loss is caused not only by the mobile communication channel but also by malicious nodes.

Therefore, the values of $\alpha_{n\rightarrow k}$ and $\beta_{n\rightarrow k}$ can be recalculated as

$$\begin{aligned}\alpha_{n\rightarrow k}^{\text{new}} &= \alpha_{n\rightarrow k} + P_{n\rightarrow k}^{\text{plr}} \times (\alpha_{n\rightarrow k} + \beta_{n\rightarrow k}),\\ \beta_{n\rightarrow k}^{\text{new}} &= \beta_{n\rightarrow k} - P_{n\rightarrow k}^{\text{plr}} \times (\alpha_{n\rightarrow k} + \beta_{n\rightarrow k}),\end{aligned} \tag{16}$$

where $P_{n\rightarrow k}^{\text{plr}}$ is the packet loss rate. Similar to [31], the packet loss rate is estimated by the following formula:

$$P_{n\rightarrow k}^{\text{plr}} = 1 - \frac{\sum_b^c \omega(b) \times \omega(b)}{\sum_b^c \omega(b)}, \tag{17}$$

where $\omega(b)$ is the weight value of the historical link state, and let link $= (\omega(1), \omega(2), \cdots, \omega(b))$ be the historical link state record. The weighted value is given by $\omega(b) = 2b/c(c+1)$, where b and c are the serial number and status record number of $\omega(b)$ in the link, respectively.

On the other hand, we assume that all wireless nodes have the same initial energy consumption rate and energy level. When a malicious node launches a malicious attack, it can always consume abnormal energy. Note that the initial energy consumption level of the nodes is the same. Therefore, we measure the trust of the node by the degree of change in the energy consumption level and judge whether the node is a malicious node. Let $P_{n\rightarrow k}^{\text{pen}}$ be the energy consumption rate, which is achieved by using the ray projection method [33] ($P_{n\rightarrow k}^{\text{pen}} \in [0, 1]$). Then, the node capability (NC) is given by

$$\text{NC}_{n\rightarrow k} = \begin{cases} 1 - P_{n\rightarrow k}^{\text{pen}}, & \text{if } E_{n\rightarrow k}^{\text{res}} \geq \theta, \\ 0, & \text{otherwise,} \end{cases} \tag{18}$$

where $E_{n\rightarrow k}^{\text{res}}$ and θ are the remaining energy and energy threshold of a node, respectively.

Direct trust values of nodes are calculated based on subjective logic; in this work, we evaluate the trust value of a node by a real number ranging from 0 to 1. Like most literature, such as [34, 35], the trust threshold is set 0.5. In other words, the node is trustworthy when its trust value is higher than 0.5; otherwise, it is not trustworthy. Then, the direct trust of the node is defined as

$$D_{n\rightarrow k}^{\text{direct}} = \begin{cases} 0.5 + (\text{NH}_{n\rightarrow k} - 0.5) \times \text{NC}_{n\rightarrow k}, & \text{if NH}_{n\rightarrow k} \geq 0.5, \\ \text{NH}_{n\rightarrow k} \times \text{NC}_{n\rightarrow k}, & \text{otherwise.} \end{cases} \tag{19}$$

To avoid potential security risks, we should only choose nodes with high trust values for communication. Each mobile device interacts with a node with a high degree of trust to obtain the trust value of each node and the priority of the service. The higher priority service should choose the node with the higher trust value to communicate for safer service communication.

4.3. Channel Quality Assessment. In power communication networks, we assume that different channels have the same bandwidth in the initial state, but processing services will occupy a certain amount of channel bandwidth resources. The routing algorithm metrics for communication services mainly include link stability, channel switching times, time delay, and bandwidth [12]. In addition to the above factors, the impact of high-priority services on low-priority services should also be examined, such as frequent link interruption and reestablishment and interference released by lower-priority services when higher-priority services occupy channels. In order to comprehensively evaluate the channel quality, three concepts of channel connectivity, reliability, and stability are defined as parameters to measure channel quality.

(1) Connectivity: system connectivity indicates whether the channel is connected between the user node and the base station at the current scheduling time. When the value of $L_{i,j}$ is 1, it means that the channel F_j is available for service; when it is 0, it means that the channel is not available

(2) Reliability: whether a channel is available for power communication services depends not only on connectivity but also on whether the channel is interfered by other services, sensor errors, and channel switching

Interference received from higher priority services: In the power communication network, if a higher priority service appears, the current service transmitted on the channel will be interfered by the higher priority service. Let $G_{i,j}$ be the probability that the current service is interfered by higher priority services in channel F_j; then, the probability of not being interfered can be expressed as

$$1 - G_{i,j} = \prod_{(x>i)} \left(1 - G_{x,j}\right). \tag{20}$$

For the interference caused by detection errors, when detecting the channel F_j, two detection errors may occur, namely, false detection and missed detection. Use H_1 to indicate that the channel is occupied by high-priority services, H_0 to indicate that there is no service in the channel, and P_e to indicate the probability of error detection, that is, $P_e(H_1 \mid H_0)$. This probability indicates that the high-priority service does not appear, but a detection error has occurred, and the cognitive node considers that the high-priority service appears and therefore causes the probability that the low-priority service in the channel is discarded or switched to other available channels for transmission. P_l represents the probability of missed detection, that is, $P_l(H_0 \mid H_1)$. This probability indicates that missed detection occurred when high-priority services appeared, and the cognitive node did not process the low-priority services transmitted in the channel, resulting in high-priority services and low-priority services, the probability of a collision. Therefore, for channel F_j, the probability of detection error is

$$E_j = P_e(H_1 \mid H_0) + P_l(H_0 \mid H_1). \tag{21}$$

When a service loses its current channel, the system will allocate another available channel to the user. This will cause

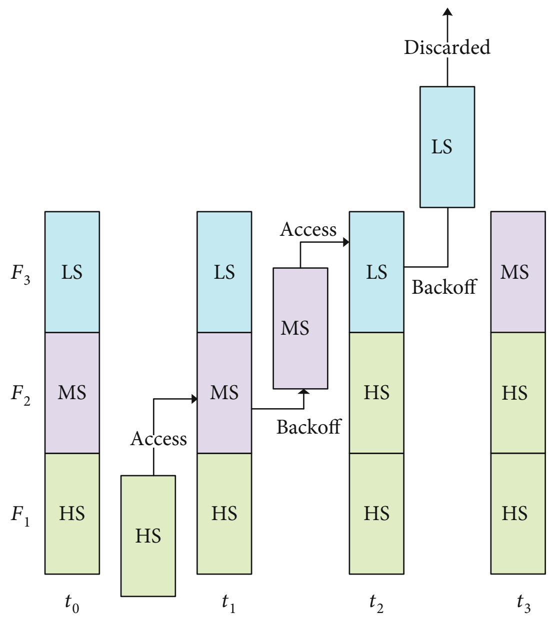

Figure 3: Priority-based channel scheduling strategy.

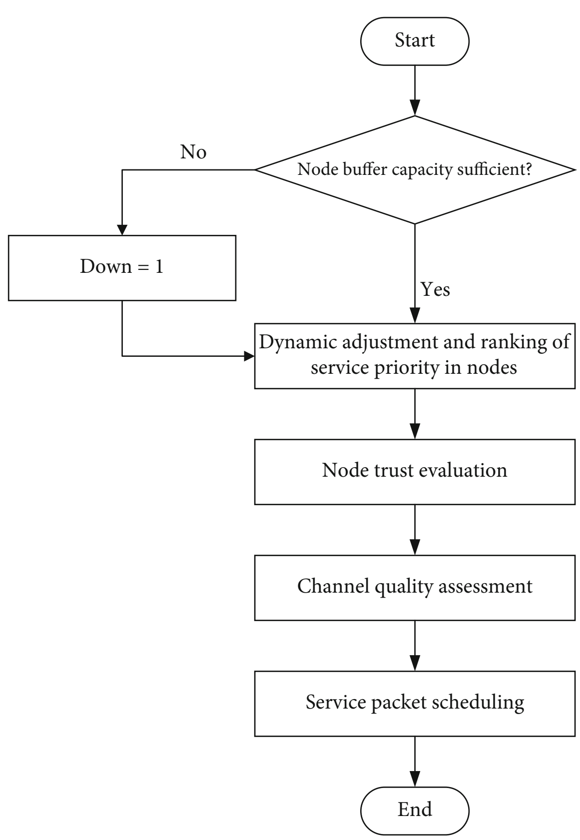

Figure 4: Flow chart of power wireless communication service packet scheduling mechanism based on dynamic priority.

interference from the switched user to the original user in the new channel. Therefore, T_j can be used to represent the interference caused during channel switching.

Table 3: Simulation parameter setting.

Simulation parameters	Parameter value setting
Number of nodes	100
Simulation time (simulation)	24 h
Message TTL	30 min
Node minimum speed	0.5 m/s
Node maximum rate	1 m/s
Node communication range	20 m
Minimum number of copies L	8
Initial constant P_{ini}	0.75
Decay weight γ	0.97
Transfer weight β	0.25
Message size range	[100, 300] kb

The available channel resource information can be obtained from the information exchange between neighboring nodes. For node i, the reliability of channel F_j can be obtained by calculating two types of interference probabilities:

$$K_{i,j} = \left(1 - G_{i,j}\right)\left(1 - T_j\right). \tag{22}$$

(3) Channel stability: stability refers to the ratio of the time when there is no service in the channel and the total time within a period of time. The channel state can be modeled as an ON-OFF model, which is an alternate update process. ON (occupied by business) and OFF (idle) duration obey the exponential distribution of parameters λ and μ, respectively [36], which are represented by T_{ON} and T_{OFF} random variables. In the model, the process of business from ON to OFF to ON in the channel is regarded as a cycle; then, the stability W_j of channel F_j is the update period length from ON to OFF to ON and the reference value of the relative stable update period length, the ratio of R. W_j can be expressed as

$$W_j = \frac{E(T_{\text{ON}}) + E(T_{\text{OFF}})}{R_j} = \frac{1/\mu_j^{\text{PU}} + 1/\lambda_j^{\text{PU}}}{R_j} = \frac{\mu_j^{\text{PU}} + \lambda_j^{\text{PU}}}{\mu_j^{\text{PU}}\lambda_j^{\text{PU}}R_j}, \tag{23}$$

where T_{ON} is the length of time that the channel is occupied by the service, T_{OFF} is the length of time that the channel does not have a service, $\mu_j^{\text{PU}}$is the number of times the channel F_j is occupied by the service in a unit time, and λ_j^{PU} is the number of times the channel is idle in a unit time.

In summary, for node i, the channel quality parameter $V_{i,j}$ of channel F_j can be expressed as

$$\begin{aligned} V_{i,j} &= L_{i,j}\left[\gamma K_{i,j} + (1\text{-}\gamma) W_j\right] \\ &= L_{i,j}\left[\gamma\left(1 - Z_j\right)\left(1 - G_{i,j}\right)\left(1 - E_j\right)\left(1 - T_j\right) + (1\text{-}\gamma) W_j\right], \end{aligned} \tag{24}$$

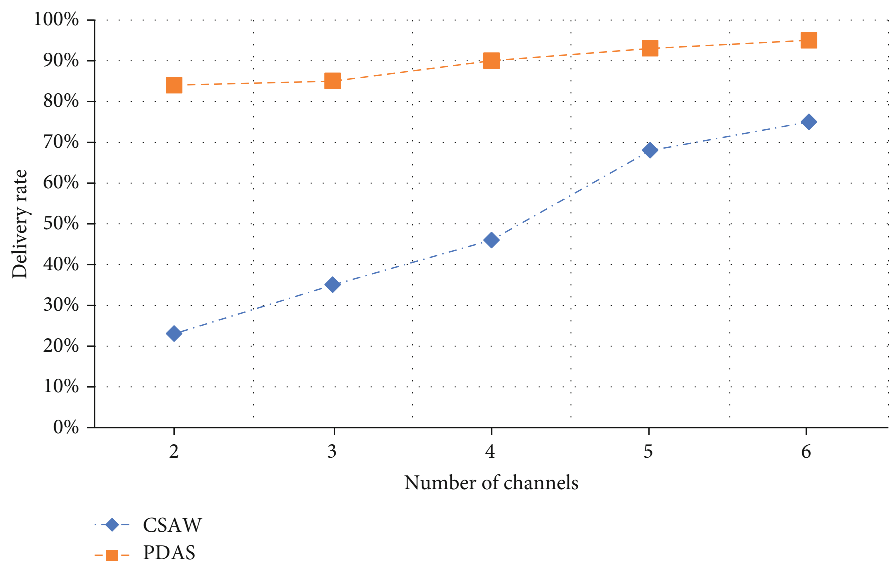

Figure 5: Delivery rate of the H service.

where γ is the weighting coefficient, which can be adjusted according to the network characteristics and service requirements and at the same time can reflect the network's emphasis on reliability and channel stability.

4.4. Packet Scheduling Mechanism. Due to the different access channel capabilities of different priority services, the traffic blocking situation is also different [37]. Here, we can divide into three kinds of services according to the service priority: high-priority service (HS), medium-priority service (MS), and low-priority service (LS). For LS, when all the channels are occupied by HS and MS packets, blocking occurs. It should be noted that the packets here contain packets (HS) whose priority is raised to a higher priority through a dynamic priority adjustment strategy. Each service uses idle spectrum resources to transmit data packets. If high-priority service appears again in the information transmission process of low-priority service, the low-priority service should be discarded from the channel or switched to other channels to continue transmission. In addition, the channel occupied by lower priority traffic should be selected as far as possible to prevent frequent handoff. The specific channel access, backoff, and handover strategies are shown in Figure 3.

As shown in Figure 3, at t_0 time, each service occupies the free frequency bands F_1, F_2, and F_3 for data transmission; at t_1 time, the authorized high-priority service (HS) access of F_2 forces the interruption of medium-priority service (MS) communication on F_2. MS backoff and access channel are occupied by the lowest priority service LS. At this time, the least priority LS data in the system is discarded. After a negligible delay time, at t_3 time, the system is in a stable state.

To properly schedule the packets, we select the optimal channel allocation decision through genetic algorithm (GA) and encode the entire channel allocation matrix by the minimum interval coding scheme. An individual in GA corresponds to a channel allocation scheme; the individual with the highest fitness in each generation population (channel allocation matrix) is taken as the optimal solution of the system.

4.5. Overall Flow of Algorithm. In this paper, the power communication service packet scheduling mechanism based on dynamic priority is proposed, which is divided into four steps: the dynamic adjustment strategy of service priority, evaluation of node trust value, channel quality assessment, and the scheduling of service packet, thus forming a complete power communication service data transmission process.

In the first part, the dynamic adjustment strategy of service priority determines the priority queue of the service in the node by comprehensively considering the TTL of the message in the node, evaluating the number and priority of the current copies of the service packet.

In the second part, we introduce the trust value evaluation method of wireless forwarding nodes to improve the security of data transmission.

In the third part, the channel quality is comprehensively evaluated from the three perspectives of channel connectivity, reliability, and stability.

In the fourth part, a flexible and efficient packet scheduling mechanism is designed for different priority services to allocate communication channels efficiently and improve the utilization of the system.

The algorithm is shown in Figure 4.

5. Simulation

This project is based on the simulation platform ONE and establishes the experimental simulation of the network. The node's movement model is a random walk model. The specific parameter settings of the node are shown in Table 3.

In the experiment, according to the different requirements of different services for network performance, three types of services are defined: emergency service, data flow service, and best effort service. It is defined as H class, the target delay is 800-1200 s; M class, the target delay is 1200-1800 s; and L class, the target delay is 1800-3000 s. The ratio of the number of messages generated by the system in the network simulation is 1 : 3 : 6. The algorithm proposed in this paper is abbreviated as PDAS. The experimental comparison algorithms include priority insensitive spray wait routing with congestion control (CSAW) and priority aware routing QoS policy [25]. QoS policy adapts to resource allocation in a dynamic environment and defines constraints that optimize network-wide performance while satisfying the QoS constraints of a single category. However, the contagion strategy it uses consumes a lot of resources, and scheduling information needs to be provided globally, which is not suitable for delay-tolerant networks. Practical application.

5.1. Simulation Experiment Index. In this paper, the performance of the network is measured by message delivery rate, average delay, packet loss rate, and network overhead. The calculation methods of these four indicators are slightly different from those of traditional network service quality-related indicators.

(1) Delivery rate: the ratio of the total number of messages successfully delivered to the destination node to the total number of messages generated by the source node. A copy of the same message counts as one message

$$\text{Delivery rate} = \frac{\text{the total number of messages successfully delivered to the destination node}}{\text{the total number of messages generated by the source node}} \quad (25)$$

(2) Packet loss rate: the ratio of the total number of dropped packets to the total number of messages successfully delivered to the destination node. Different copies of the same message count as multiple packets. The higher the packet loss rate, the worse the network performance

$$\text{Packet loss rate} = \frac{\text{total number of dropped messages}}{\text{the total number of messages received}} \quad (26)$$

(3) Network overhead: it is determined by the total number of forwarding messages and the total number of messages successfully delivered to the destination node. Copies of all messages included in the total number of forwards of all messages

$$\text{Network overhead} = \frac{\text{the total number of forwarding of all messages-the total number of messages successfully delivered to the destination node}}{\text{the total number of messages successfully delivered to the destination node}} \quad (27)$$

5.2. Simulation Results. The simulation mainly verifies the performance of the algorithm under different network resources. When the cache space in the network is insufficient, it will cause network congestion and affect the quality of service. Therefore, the simulation experiment mainly compares the routing conditions in different buffer spaces to compare the performance of routing algorithms.

It can be seen from Figure 5 that using PDAS can effectively improve the delivery rate of class H services. In addition, even when the network load is heavy, the delivery rate can be maintained at about 90%. This is the highest priority service in the channel. It can seize the channel occupied by other services and get more transmission opportunities.

As can be seen from Figure 6 after the adoption of PDAS, the delivery rate of class M and class L services has also improved. This is because when the network load is heavy, with the increase of queuing delay, the priority level of the packets to be transmitted is increased according to the priority dynamic adjustment strategy, so as to obtain more transmission resources.

Figure 7 shows the relationship between the packet loss rate and the number of channels. It can be seen that when the network resources are sufficient, the packet loss rates of all algorithms are gradually reduced. Because QoS policy algorithm uses infection algorithm, the redundancy of service messages in the network will still be higher than that of the spray wait routing algorithm. Therefore, even in the case of sufficient network resources, the packet loss rate of the QoS policy algorithm for low-priority services is still relatively high.

Figure 8 shows the relationship between network overhead and channel number. It can be seen that in the case of lack of network resources, the cost of the whole network is relatively large. With the increase of the number of channels, the network overhead of the PDAS algorithm proposed in this paper is low. In the PDAS algorithm, the priority of traffic and channel resources will be dynamically adjusted before entering the route, which can reduce the redundant forwarding times and reduce the network overhead. Because the QoS policy algorithm uses the infection algorithm, it is difficult to

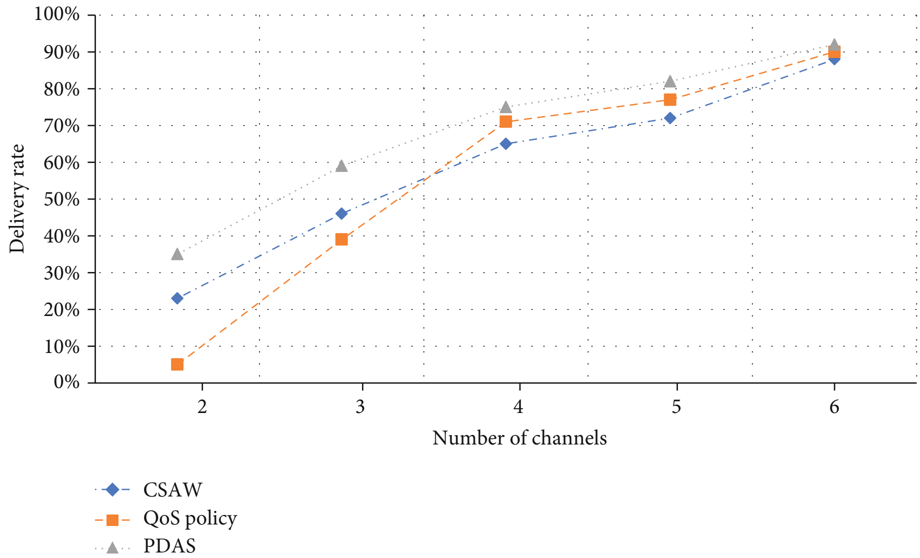

Figure 6: Delivery rate of the M service and L service.

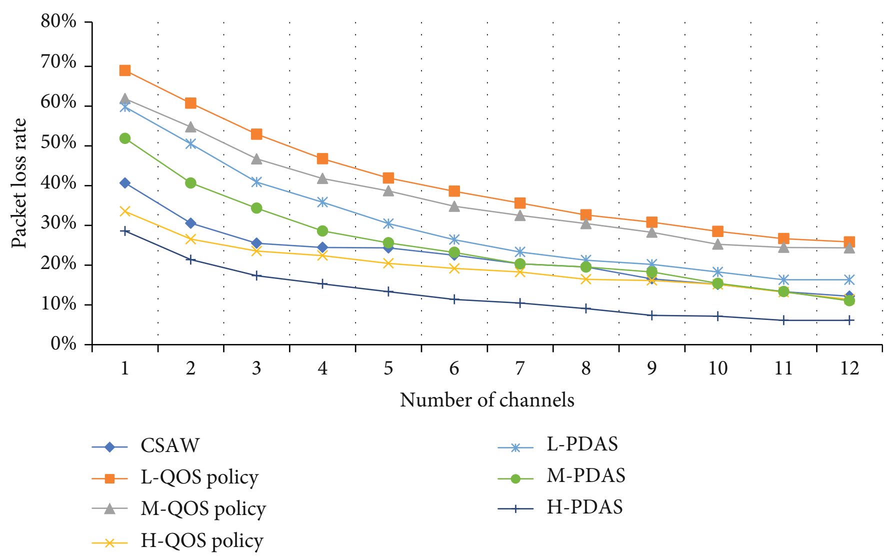

Figure 7: Packet loss rate of the algorithm.

control the redundancy of service messages in the network, but excessive redundancy will increase the number of messages to be forwarded, which will lead to larger network overhead. Although the CSAW algorithm limits the number of copies of service messages, it does not adjust the channel, so there will be unnecessary forwarding, resulting in increased network overhead.

6. Conclusions

In order to provide reliable QoS guarantee for different services under the real-time change of spectrum resources in power communication network, this paper proposes a communication service scheduling method based on dynamic priority. This method solves the problem that the traditional scheduling mechanism only considers the absolute priority of services and ignores the relative priority among services, which cannot meet the requirement of intelligent power communication network to provide differentiated QoS services for heterogeneous services. The simulation results show that by using the proposed method, the system can ensure the communication performance of services with high QoS requirements without interference and improve the utilization of the whole system. The power wireless communication network scenarios involved in this article have a certain degree of promotion and provide theoretical support for ensuring the QoS for power communication services. However, there are still some differences between the scenario

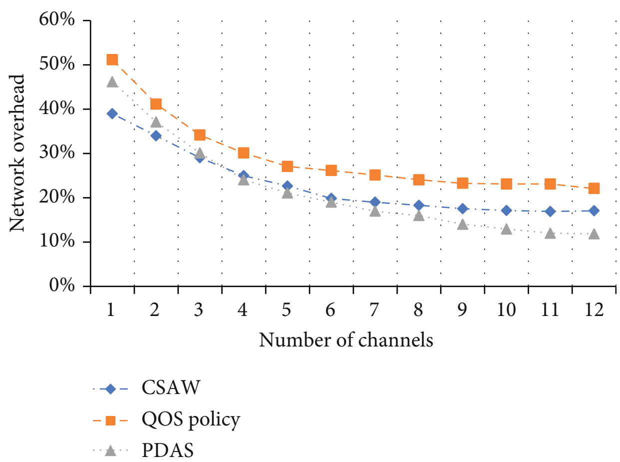

Figure 8: Network overhead of the algorithm.

set in this article and the actual network. Besides, we will consider channel multiplexing to realize simultaneous data transmission of multiple services in future research.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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