Resource Scheduling Algorithm for Power Wireless Service

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Abstract. Based on the application of LTE technology in smart grid construction, this paper studies the technical background and demand of LTE technology and carrier aggregation technology in smart grid communication network construction, and analyzes the technical principle and technical background of LTE and carrier aggregation technology used in smart grid. Aiming at the problem of insufficient spectrum resources in smart grid construction, this paper focuses on the combination of carrier allocation and wireless resource allocation faced by carrier aggregation technology in smart grid environment. Carrier aggregation technology is used to improve spectrum utilization and speed up transmission speed. This paper studies a joint resource scheduling algorithm based on service priority, evaluates the service priority by studying the characteristics of wireless private network, and designs different scheduling methods for different services according to the characteristics of wireless resource allocation. The ns-3 simulation results show that the algorithm can provide sufficient resource allocation for high QoS services in the case of traffic congestion, balance the relationship between fairness and throughput, and improve the service transmission performance.

1. Introduction
The rapid development of wireless communication technology promotes the continuous development of information technology in the whole society. The ubiquitous high-quality data service and multimedia communication are the goal of building the information society. At present, one of the research directions of wireless communication is smart grid. The core concept of smart grid is to apply advanced communication technology to power grid communication and improve the communication ability of power industry. In the new generation of power network required by smart grid, the allocation and management of power should be based on the good communication ability and strong computing ability of both sides of power generation and consumption, so as to ensure the efficient control, energy efficiency, reliability and security of the whole power network. The latest two-way interactive technology will be used by both sides of power generation and consumption of smart grid. Through smart grid, both sides of power generation and consumption can negotiate and control the smart power equipment in the home or building, which can save energy, reduce costs, improve the safety and efficiency of power consumption, and even improve the transparency of the whole power industry. The modernization of the traditional power grid has greatly improved the management, protection, optimization, automatic control, expansion and other aspects of the users connected to the power grid. Its coverage includes but not limited to traditional central power plants, new energy power generation equipment, power distribution systems, factories, household electricity users and electric vehicles and other intelligent equipment that will be more popular in the future[1-4]. In view of these kinds of access equipment and functional requirements, the construction of smart grid needs a basic network with strong two-way interaction ability, which is jointly constructed by power flow and information flow. Smart grid is proposed to solve the problem of
information transmission from the generation side, through the transmission link, power distribution link, and ultimately to the consumers. On the basis of ensuring the connection of power resources from generation end to consumption end, building a more complex power system with better effect is the goal of building smart grid.

In order to solve this problem[5], this paper will further study and discuss LTE technology, and give the theoretical basis of selecting carrier aggregation technology, and further optimize the resource scheduling problem in the power wireless private network.

2. Establishment of carrier resource scheduling model

2.1. Power Business Priority

There are many kinds of business in smart grid, and according to the development plan of smart grid[6], it will also carry more kinds of business in the future. In this paper, three representative services of Electricity Information Collection (EIC), Distribution Automation (DA) and Video/Image Surveillance (VIS) are selected, and corresponding QoS function is designed according to the priority of communication service. It is set here that EIC service has the lowest priority, DA service has the medium priority and VIS service has the highest priority.

- The collection object of Electric Information Collection (EIC) system is all power users, including all kinds of large, medium and small special transformer users, all kinds of 380/220V power supply industrial and commercial users and residential users, public distribution transformer assessment and measurement points. At present, the power consumption information collection service is mainly transmitted by 230 data transmission stations and GPRS system[7]. In a word, the power information acquisition service has the characteristics of low speed requirements and low real-time requirements.

- The distribution automation (DA) service can also be used for specific location power telemetry, remote control, data transmission and other services. In the research of smart grid, it not only includes power load control, but also covers the integrated management and application of services in the grid. Distribution automation should aim at improving the reliability of power supply, improving the quality of power supply, improving the efficiency of power grid operation and meeting the needs of customers.

Video/image surveillance (VIS) in power grid is mainly used in power construction site, key section of transmission line, emergency command and accident handling site, transformer substation and other important operation and operation sites, major activities power conservation site, etc. At present, there is no unified specification for video monitoring in the power industry. However, most of them use cable channel (optical fiber or cable) to transmit high-definition video (720p/1080p/1080i), and the data bandwidth of single channel video is about 4 Mbps[8-10]. Video image monitoring service has the characteristics of burst, large bandwidth demand and wide coverage demand.

2.2. Multi Band Carrier Aggregation Scenario

As shown in Figure 1, the scenario of mixed coexistence of multi band aggregation terminal and single band terminal in power wireless private network is shown. Among them, the Yellow terminal is a multi-band aggregation terminal with aggregation capability, which can use three frequency bands within the coverage at the same time. Other color terminals are LTE R8 type terminals with single frequency band, and can only use the band with the same color.
In this paper, we consider three scenarios of mixed coexistence of different services. In order to provide different QoS Network Services for different services, data packets are transmitted through radio bear in LTE protocol stack. The real-time service data packet is transmitted by guaranteed bit rate (GBR), and the non real-time service data is transmitted by non GBR bearer.

The packet size of the three services is represented by $M_{\text{packet}}$, and the packet arrival interval is represented by $T_{\text{packet}}$. In order to guarantee the QoS of each service, the minimum rate provided by GBR bearer is as follows:

$$r_{\text{min}} = \frac{M_{\text{packet}}}{T_{\text{packet}}}$$  (1)

In order to achieve the tradeoff between network throughput, user fairness and packet loss rate, this paper uses the priority based on fairness and delay to guide RB allocation. The calculation formula of UE priority on RB is as follows:

$$Q_{i,j,k} = \frac{r_{i,j,k}}{r_j} f(\tau_i)$$  (2)

$\tau_i$ in equation (2) represents the waiting time of the first queue packet in the cache queue of terminal $i$, $f(\tau_i)$ is used to improve the priority of video stream packets with long waiting time in RB allocation, so as to transmit video stream packets with long waiting time in RB allocation:

$$f(\tau_i) = \begin{cases} \exp\left(\frac{\tau_{\text{max}}}{\tau_{\text{max}} - \tau_i}\right), & \tau_i < \tau_{\text{max}}, i \in U_{\text{video}} \\ 0, & \tau_i = \tau_{\text{max}} \end{cases}$$  (3)

$U_{\text{video}}$ in formula (3) represents the collection of all video stream UE, $\tau_{\text{max}}$ represents the maximum waiting time that video stream packets can tolerate. When $\tau_i > \tau_{\text{max}}$, the waiting packets of the queue head will be discarded, and the original second packet will be changed into the head of queue packet, and $\tau_i$ and $f(\tau_i)$ will be recalculated according to the packet.

2.3. Multi Service and Correlation Factor

In order to quantitatively evaluate the correlation between different services and different frequency bands, the correlation factor $\alpha_{i,j}$ between services and frequency bands is calculated by using frequency band and service characteristics, $\alpha_{i,j} \in (0,1)$. The larger $\alpha_{i,j}$, the more suitable the $j$ band is to transmit the service data of the $i$ terminal. In order to quantitatively evaluate the instability of the unlicensed frequency band, the average access delay $D_j$ of the $j$ band of LTE-U is introduced. For the authorized band, $D_j = 0$ because LET-U can be accessed continuously. $D_j$ can be calculated by LBT’s back off mechanism. Obviously, the larger the bandwidth BW of the frequency band is, the more suitable the services with high speed requirements; the smaller the $D_j$, the more suitable for real-time service transmission. In order to reduce the interference of human factors in the process of calculating the
matching degree, this paper uses the gray relational analysis (CRA) algorithm to calculate the correlation factors. The gray correlation factor between the $j$ frequency band and the $i$ terminal is calculated as follows:

$$GCF_{ij} = \frac{1}{\epsilon_{ij} + \epsilon_{j} + \epsilon_{i} + 1}$$

(4)

$\epsilon_{i, BW}$ and $\epsilon_{i, D}$ in equation (4) represent the demand coefficient of bandwidth and delay of the service of the $i$ terminal. The larger $\epsilon_{i, BW}$, the higher the bandwidth demand of the terminal services. Similarly, the larger the $\epsilon_{i, D}$, the more stringent the delay requirement. Finally, the correlation factor between the service of the $i$ terminal and the $j$-band can be obtained by normalization of $GCF$.

$$\alpha_{ij} = \frac{GCF_{ij}}{\sum_j GCF_{ij}}$$

(5)

### 2.4. Utility Function Based on Correlation Factor

After getting the correlation factor between service and frequency band, we can further define the utility function in the process of resource allocation. The larger the value of utility function is, the more reasonable the resource allocation is:

$$u_{i,j,k} = F(\alpha_{i,j}, r_{i,j,k}, r_i, T_i) = \alpha_{i,j} \frac{r_{i,j,k}}{r_i} f(T_i)$$

(6)

In formula (6), $r_{i,j,k}$ represents the transmission rate obtained by assigning the $k$-th RB(Resource Block) on the $j$-th band to the $i$-th UE, which can be obtained through the CQI feedback of UE; it is the historical average rate of the $i$-th terminal; and represents the waiting time of the queue header packet in the $i$-th UE cache. Among them, $\frac{r_{i,j,k}}{r_i}$ represents the fairness of resource allocation. The more equitable the resource allocation is, the higher the utility value of the network will be. $f(T_i)$ takes the definition of formula (3), which means that the longer the transmission waiting time, the greater the utility value.

### 3. Resource scheduling algorithm based on service priority

The purpose of resource scheduling algorithm is to maximize the total utility of the network, as shown in formula (7). In LTE-U multi band aggregation system, there is an authorized band and an unauthorized band, so the band index $J = 1, 2$. The period of resource scheduling is one LMS, and the RB of two time slots in each frequency band is reallocated every 1ms.

$$\max \sum_{j=1}^{M} \sum_{i=1}^{N_j} \sum_{k=1}^{M_i} \alpha_{i,j} \frac{r_{i,j,k}}{r_i} f(T_i)$$

$$s.t. \quad r_i = \sum_{j=1}^{M} \sum_{k=1}^{M_i} b_{i,j,k} r_{i,j,k} \geq r_{i, min}, i \in U$$

(8)

(9)

$$\sum_{i=1}^{U} b_{i,j,k} = 1, h_{i,j,k} \in \{0,1\}, j \in M$$

$$\sum_{i=1}^{U} P_i \leq P_{i, max}, i \in U$$

(10)

Where $u$ is the set of all end users and $M$ is the set of available frequency bands for end users. The formula (8) is used to guarantee the minimum rate of GBR in the process of ensuring resource scheduling, where $r_{i, min}$ uses the calculation method of formula (1). Equation (9) indicates that an RB can only be assigned to one terminal in a TTI. Equation (10) indicates that the sum of the transmission power of each end user in the cell is less than the maximum transmission power of the base station.

The steps of resource allocation algorithm in this paper are as follows:
1. Power business priority division. Firstly, all power user terminals are divided into three sets $U_{IS}$, $U_{DA}$, and $U_{EC}$ according to the service type, and the terminals in each set are sorted according to $r_{i,j}^k f(\tau_i)$.

2. Establishment of resource scheduling model. 1) In the process of resource scheduling, the minimum rate of power user service is ensured. 2) RB can only be allocated to one terminal in a TTI. 3) the sum of the transmission power of each end user in the cell is less than the maximum transmission power of the base station. Taking the above three problems as constraints of resource scheduling model and user utility function as objective function, a resource allocation model is established.

3. Sub channel allocation. The dynamic iterative algorithm is used to allocate temporary subchannels to users, and then the subchannel allocation method is obtained. In the first dynamic iteration, it is assumed that the power is evenly distributed, and then the subchannel allocation is updated by water injection algorithm.

$$i_j = \arg \max \alpha_{i,j}$$

Where $i_j$ indicates that subchannel j is temporarily allocated to user i. Formula (11) indicates that the higher the correlation between user services and frequency band, the frequency band will be allocated to users first.

4. User power distribution. On the premise of subchannel allocation, the user power is allocated, and the power allocation mode is obtained when the transmission power is high.

5. Repeat step 3 to get the user's next temporary subchannel, and update the subchannel allocation method according to equations (11).

6. Iterating N times until the utility value of the objective function is maximum, the optimal solution of single cell transmission is obtained, and the power user chooses the resource allocation method of the optimal solution for data transmission.

4. Simulation results and analysis

In this paper, the NS3 simulation platform is used to build the simulation environment. According to the definition of LTE and 3GPP TS 36.104 standard, this paper configures a fading model with UE speed of 3km/h for urban scenes, as shown in Figure 2. The three log distance propagation loss model is used for path loss. Other simulation environment parameter settings are shown in table I.

| Parameter               | Value                                             |
|-------------------------|---------------------------------------------------|
| System type             | Single cell                                       |
| Cell radius             | 1km                                               |
| System bandwidth        | 5MHZ                                              |
| Fading model            | fading_trace_EPA_3kmph                            |
| Path loss model         | ThreeLogDistancePropagationLossModel              |
| User number             | 10-00                                             |
| User distribution       | 1:1 uniform distribution of users in the center and edge of the cell |
| Simulation time         | 10000TTLs                                         |
| scheduling algorithm    | RR/MT/PF/SPA                                      |

The meaning of each simulation parameter is as follows:

(1) The fading trace EPA 3-kmph fading model is defined by LTE standard, which simulates the fading situation when pedestrians walk at the speed of 3 km/h.
(2) The path loss model selected by simulation: ThreeLogDistancePropagationLossModel, the speed of channel fading varies with the distance between the user and the base station.

Figure 2 Urban fading model with UE speed of 3km/h.

In this paper, JRS algorithm, Round Robin (RR) algorithm, Maximum Throughput (MT) algorithm and Proportional Fair (PF) algorithm are simulated, and the main performance of these algorithms is evaluated and analyzed. Finally, the simulation data is drawn and analyzed.

Figure 3 Change curve of uplink throughput with the number of households

As shown in Figure 3, the average throughput of the three types of users in the SPA algorithm designed in this paper shows an upward trend with the increase of the number of cell users, which is the same as the overall trend of MT algorithm. The overall average throughput of the four scheduling algorithms is: MT > SPA > PF > RR. With the increasing number of users, the gap between SPA and MT tends to narrow. Since the spa algorithm takes into account the priority of services and the fairness of different services in the allocation of wireless resources, the throughput increases slowly when the number of users is greater than 60.
Figure 4 shows the comparison of the fairness factor changes of RR, SPA, PF and MT algorithms with the increase of the number of cell users. It can be seen that with the increase of the number of users, the fairness of the four kinds of algorithms shows a downward trend. But SPA algorithm and PF algorithm maintain high fairness, but slightly lower than RR algorithm, this is because when the user's transmission rate is lower than the guaranteed bit rate required by the service, the user will be forced to schedule, which makes the user's fairness slightly reduced. With the increase of the number of users, the channel state condition of MT algorithm is relatively poor, which makes it difficult for users to get scheduling opportunities, and the overall fairness of the system drops faster. In contrast, spa algorithm takes into account the priority of power business, so the overall fairness of users is still very good.

As can be seen from Figure 5, the overall transmission delay of SPA presents an upward trend. With the increase of the number of users, the channel transmission quality decreases and the transmission delay increases. In order to make every user have the opportunity to transmit resources, although the fairness of users is guaranteed, the delay is the largest. SPA allocates wireless resources to users on the premise of ensuring the fairness of users, and the experiment decreases compared with RR. When the number of users is less than 20, the delay of spa and MT is almost the same. As the number of users increases, the delay of JRS increases, and the performance decreases, but it is still lower than the delay of RR.
5. Conclusions
In this paper, firstly, the business characteristics of smart grid communication are analyzed, and then the typical business requirements are prioritized, and the LTE users of smart grid are divided into three categories. The corresponding relationships are: low priority of power consumption information collection business, medium priority of distribution network automation business, and high priority of emergency repair and line monitoring business. Aiming at the problem of insufficient spectrum resources in smart grid construction, this paper focuses on the combination of carrier allocation and wireless resource allocation faced by carrier aggregation technology in smart grid environment. Carrier aggregation technology is used to improve spectrum utilization and speed up transmission speed. On this basis, a joint resource scheduling algorithm based on service priority is studied. By studying the characteristics of power wireless private network carrying services, the service priority is evaluated. Combined with the characteristics of TD-LTE resource allocation, different scheduling methods are designed for different services. The performance of the algorithm is simulated by ns-3, and the configuration, compilation and deployment of the simulation platform are introduced. Finally, by comparing the performance of several algorithms, it is found that the algorithm with good throughput performance has poor fairness, while the algorithm with good fairness has poor throughput. The performance of spa algorithm in this paper is between RR and MT, not only that, compared with the previous throughput simulation curve, this paper based on the service priority resource scheduling algorithm according to EIC, Da, VIS three kinds of power business priority resource allocation, a good balance between fairness and throughput - on the premise of not losing too much fairness, further improve the unit cell frequency Spectrum utilization efficiency.

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