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Research on Service Support Ability of Power Wireless Private Network

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Abstract. In view of the problems of electric power wireless communication and to serve the power consumer better, on the basis of the basic principles of TD-LTE's network structure, traffic model of power service is analyzed in detail, and in the actual case, through the data processing method and comparison analysis method, the technical parameters, theoretical analysis and field test results of 1.8 G and 230 M LTE systems are compared, and the ability of power wireless private network to support power service is verified. The analysis and testing provide a technology support for electric power communication access network construction and lays the foundations for popularization and application of LTE power wireless private network.

Keywords: TD-LTE · Wireless private network · Hybrid networking · Traffic model · Bandwidth analysis

1 Introduction

With the development of the construction of smart grid, the types of power communication services are becoming more and more abundant, network coverage and construction scale are expanding year by year [1–3]. In order to support the core tasks and objectives of smart grid construction, it is necessary to construct a terminal access network that has a wide access and flexibility [4, 5].

Fiber access network has many advantages, such as high bandwidth, anti-interference, anti-damage, security, reliability and so on. It is the best access method of user experience [6]. However, there are many problems in fiber-optic access network, such as the difficulty of laying, the long construction period, the long time of fault recovery, the high cost of investment, and so on, which can not meet the needs of mass access or mobile access [7]. Wireless technology system becomes a necessary supplement to optical fiber access.

At present, we mainly use the way of public network leasing to realize [8, 9], this approach has the following problems, one is that many intranet service applications can not be extended to the wireless terminal of the outer network, the second is that applications with high bandwidth requirements, such as pictures and videos, will generate expensive traffic costs, the third is restricted by the national network information security factors, video surveillance and other services can not access the intranet, there is a lot of inconvenience in the application of the business. In addition,

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with the development of clean energy substitution and electric energy substitution, distributed photovoltaic, electric vehicle charging piles and other business will be explosive growth [10, 11]. Power wireless private network is one of the most important technologies to realize access and acquisition of power network terminal services, therefore, more and more attention has been paid to the establishment of power wireless communication broadband private network based on special authorized frequency band [12, 13]. In order to ensure that the construction of power wireless private network can meet the current and even future needs of power business applications, in this paper, the traffic model of electric power business is obtained at the present stage and on this basis, the power service support capability of power wireless special network is analyzed and verified.

2 Architecture of Power Wireless Private Network

2.1 Base Station

The base station is generally located in the power supply building [14], including network management platform, monitoring center, data center, etc. The network management platform is mainly responsible for network state monitoring, fault diagnosis and alarm. At the same time, it can integrate the existing electric power information management, and form a unified dispatching command system on the basis of various multimedia means and GIS (Geographic Information System) technology, mainly including dispatching command center, field emergency command and dispatch system, videophone scheduling system and monitoring system.

2.2 Core Network

The core network is directly connected to the base station [15]. It mainly provides the connection for the user, manages the user and carries the service, including responsible for terminal authentication, terminal IP address management, mobility management, etc. The core network of the power wireless private network system can provide basic services including distribution automation, load management, power information collection, emergency repair and maintenance, dispatching command and visual management of mobile assets, etc.

2.3 Terminal

Terminal equipment module is the general name of remote terminal modules such as user data acquisition, power monitoring and dispatching, power video transmission, etc. It is the executive unit of information collection and monitoring and dispatching in Internet of things terminal, such as collector, concentrator, control switch and so on. The wireless terminal (also referred to as the UE) and the base station are air interfaces that provide communication between the terminal device and the base station.

3 Bandwidth Analysis

We use Okrmuram-Hata model to calculate the coverage ability of power wireless private network system. The model is established according to the measured data, which provides complete data and is widely used in 150–1920 MHz frequency band. The basic transmission loss formulas of Okumuram-Hata model in different propagation environments are as follows

$$\begin{aligned}\Delta = {} & 69.55 + 26.16 \times \log_{10}(f_c) - 13.82 \times \log_{10}(h_t) + \\ & (44.9 - 6.55 \times \log_{10}(h_t)) \times \log_{10}(d) - \\ & ((1.1 \times \log_{10}(f_c) - 0.7) \times h_r - 1.56 \times \log_{10}(f_c) + 0.8) + C\end{aligned} \tag{1}$$

where f_c is the working frequency, h_t is the effective antenna height transmitted by the base station, h_r is the effective antenna height received by the terminal, and d is the overlay distance, and C is the environmental compensation factor, the value is as follows

$$\begin{cases} city: \quad C = 0 \\ suburbs: \quad C = -2 \times \left(\log_{10}(f_c/28)\right)^2 - 5.4 \end{cases} \tag{2}$$

When the path loss is achieved, the link budget is then analyzed. Assume that the transmission power of the signal is p (dBm), Then the sensitivity of the receiver is $p - \Delta$ (dBm). If the bandwidth of the signal is π (dB-Hz), the noise coefficient of the receiver is ζ (dB), and the corresponding noise power of the receiver is $\pi + N_0 + \zeta$ (dBm), where N_0 (dBm/Hz) denotes the noise power spectral density (−174 dBm/Hz). It is known that the minimum receiving SNR of the receiver is $\Gamma = (p - \Delta) - (\pi + N_0 + \zeta)$, which is also the minimum SNR that requires the receiving device to be able to work.

Since power infrastructure mainly depends on the uplink data transmission, the capacity of uplink is analyzed here. In the uplink, the uplink signal transmitted by the user device can take up all of its transmit power, $p = P_{UL}$. The corresponding receiving SNR on the receiving end is

$$\Gamma = (P_{UL} - \Delta) - (\pi + N_0 + \zeta) \tag{3}$$

And then use the modified Shannon formula

$$r = \pi \cdot \log_2(1 + \beta \cdot \Gamma) \text{ (bit/s)} \tag{4}$$

The calculation of the channel capacity is carried out, where β is the compensation parameter used to compensate for the theoretical formula and the actual situation.

To simplify the analysis, a cell is divided into three regions according to SNR, as shown in Fig. 1. The three regions are 20 dB regions with SNR above 20 dB, 10 dB region with SNR between 10 dB and 20 dB, and 0 dB region with SNR between 0 dB and 10 dB. In urban environment, the corresponding radius of the three regions are

0.75 km, 1.45 km and 2.8 km, respectively. In the suburban environment, the radius of the three regions are 1.65 km, 3.2 km and 6.1 km respectively. The area percentage and spectral efficiency of each region are given by simulation, as shown in Table 2.

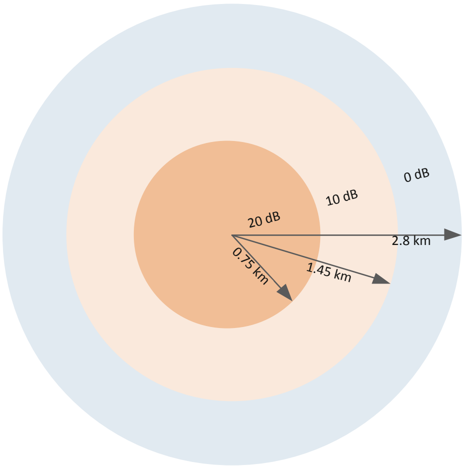

Fig. 1. Plot diagram of district division

The average transmission rate per RB can be expressed as

$$\bar{r} = \sum_{n=1}^{3} r_n b \alpha_n = r_1 b \alpha_1 + r_2 b \alpha_2 + r_3 b \alpha_3 \text{ (bits/RB)} \quad (5)$$

b=144 is the number of available resources per RB, r_i is the spectral efficiency of the region in Table 1, and α_i is the area percentage of the region in Table 1. Bring the data from Table 1 to get the average number of bits transmitted by a single RB $\bar{r} \approx 200$ bits/RB. It is worth noting that the average rate is basically the same because the percentage of area between the city and the suburb is similar. The transmission rates that each RB can support can be represented as

Table 1. Area percentage and spectral efficiency of each region within the cell

	Area percentage %	Spectral efficiency bits/s/Hz
20 dB	$\alpha_1 = \begin{cases} 7.2, & urban \\ 7.3, & \text{suburban} \end{cases}$	$r_1 = 4.9$
10 dB	$\alpha_2 = \begin{cases} 19.6, & urban \\ 20, & suburban \end{cases}$	$r_2 = 2.5$
0 dB	$\alpha_3 = \begin{cases} 73.2, & city \\ 72.7, & suburban \end{cases}$	$r_3 = 0.82$

$$\bar{r} = 200 \times 0.6/0.001 = 120 \text{ kbps} \tag{6}$$

Table 2 shows the number of power terminals to be accommodated in each cell by 2020 and the requirements of different power infrastructure services for wireless communication transmission rates. For wireless meter reading, there are currently two solutions, one is that 1 poll per day, 300 KB per poll, including positive and negative active power, voltage and current power, daily freezing data, etc., and another is that 1 h 1 poll, 28 kB each time, additional 1 day 1 poll, 8 KB each time. For cities, an average of 92 m are hung by a single concentrator, and 53 m by a single concentrator in suburban areas.

Table 2. The demand of wireless communication rate for power basic service

Type of traffic	Single terminal transmission rate	Number of terminals in cell	Total rate demand (kbps)
92 m hanging under concentrator	300 KB/day	485	13.5
92 m hanging under concentrator	28 KB/hour + 8 KB/day	485	30.5
53 m hanging under concentrator	182 KB/day	763	12.85
53 m hanging under concentrator	20 KB/hour + 6 KB/day	763	34.33
Load control	6 MB/month	Urban: 365 Suburban: 277	Urban: 6.8 Suburban: 5.1
Distribution automation	800 MB/month	Urban: 83 Suburban: 84	Urban: 205 Suburban: 207
Distributed photovoltaic	100 MB/month	Urban: 10 Suburban: 250	Urban: 3.1 Suburban: 77.1
Charging pile	150 MB/month	Urban: 150 Suburban: 235	Urban: 69.5 Suburban: 108.8

According to Table 2, these four types of basic power services require approximately 315 kbps (cities) and 433 kbps (suburbs) for transmission rates, as a result, at least 3 RBs and 4 RBs need to be reserved for urban and suburban areas, respectively. Considering the overhead of uplink control channel, at least 1.4 MHz bandwidth is required for TD-LTE system, which is exactly the minimum bandwidth of existing LTE system.

It can be seen from Table 2 that power distribution automation requires the highest transmission rate in four types of services. But with the progress of science and technology, the collection of electricity information will become particularly important. In general, the minimum bandwidth requirement for a power wireless private network is 1.4 MHz if only basic power services are considered. When the user information acquisition interval is reduced to 5 min, the minimum bandwidth is 3 MHz. When it is necessary to transmit the data of distribution automation with high precision, the minimum bandwidth is 5 MHz. The minimum bandwidth required to support other extended services, such as video conferencing, emergency repair, etc., is 10 MHz.

4 Road Survey

4.1 Test Location Selection

The total area of the test area is 927.68 km^2. At present, the area has been fully covered by 230 M wireless private network, and 14 base stations have been set up. Through careful planning, and considering the system capacity, coverage and other problems, the average radius of the base station is set to 4.8 km.

The contrast test of LTE1.8 G and 230 M is within the 5 km coverage radius of a base station. A representative wireless communication scene is selected for field measurement, and the throughput, delay and diffraction capability are compared and tested. In the north, a variety of sheltered environments, such as visual field transmission, buildings, bridges and trees, were selected for community coverage testing.

4.2 Relationship Between Distance and Throughput

The uplink transmit rate can reach 10 Mbps in the 1.8 G wireless private network when the distance between the base station and test point is about 2 km, and the downlink transmit rate can reach 12.5 Mbps. It can support the application of video conference. The uplink transmit rate can reach 2 Mbps when the distance between the base station and test point is about 3.5 km, and the downlink transmit rate can reach 5 Mbps. It can support the application of power data monitoring. The uplink transmit rate can reach 0.5 Mbps when the distance between the base station and test point is about 5 km, and the downlink transmit rate can reach 0.8 Mbps. It can support the application of power data monitoring (Figs. 2 and 3).

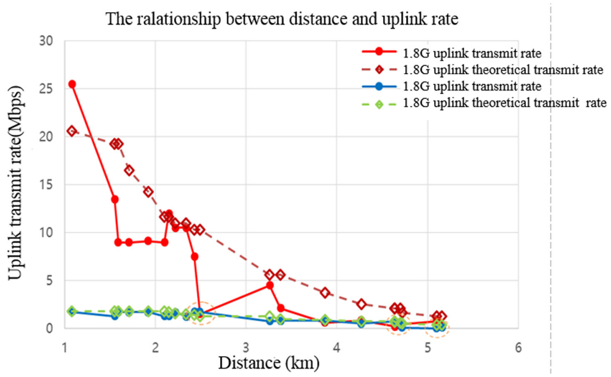

Fig. 2. Comparative diagram of the relationship between test distance and uplink rate

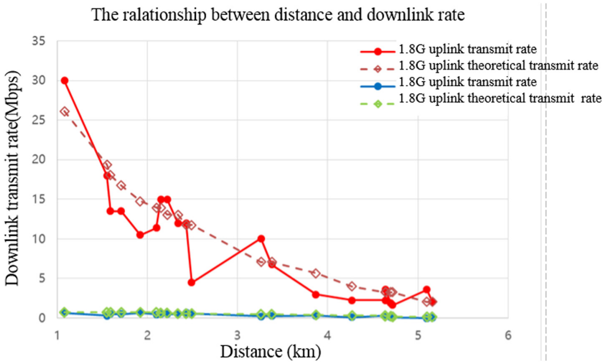

Fig. 3. Comparative diagram of the relationship between test distance and downlink rate

The uplink transmit rate can reach 1.5 Mbps in the 230 M wireless private network when the distance between the base station and test point is about 2 km, and the downlink transmit rate can reach 0.5 Mbps. The uplink transmit rate can reach 800 kbps when the distance between the base station and test point is about 3.5 km, and the downlink transmit rate can reach 300 kbps. It can support the application of power data monitoring.

4.3 Relationship Between Distance and Delay

The bidirectional average delay of 1.8 G is within 50 ms, and the packet loss rate is "0". one-way transmission delay of 230 M is about 140 ms (Fig. 4).

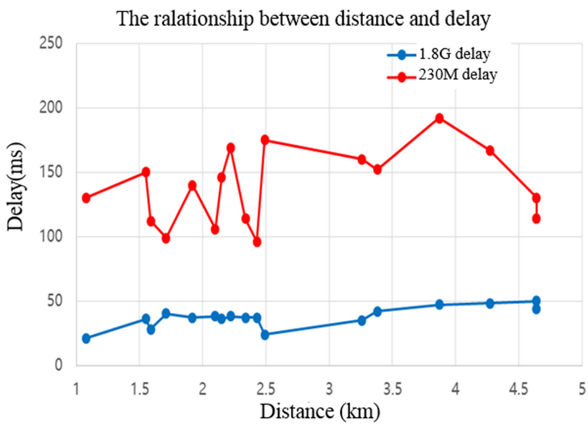

Fig. 4. Comparative diagram of the relationship between test distance and delay

4.4 Relationship Between Distance and Traffic Support Capability

By comparing the technical parameters of 1.8 G and 230 M, the theoretical analysis and field test results show that, in addition to being slightly superior to the former in terms of cell coverage radius, the 230 M system is much weaker than the 1.8 G system in terms of throughput, delay, service support capability, and the smoothness of subsequent technology evolution, and can only support static state. Small amount of basic power business. Therefore, 1.8 G is more suitable for urban area, and 230 M has a certain coverage advantage in suburbs and rural areas, which is about 1.6 times of 1.8 GHz, suitable for the construction of special network of small granular area with fewer service terminals (Figs. 5 and 6).

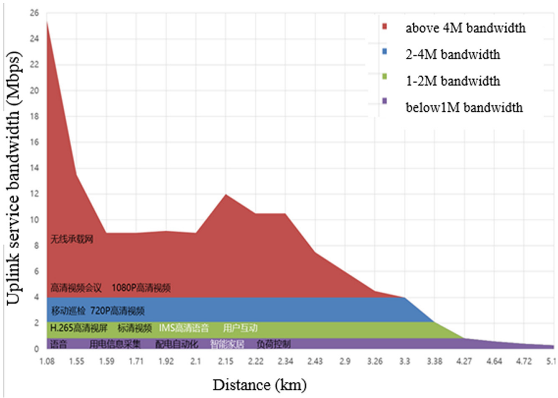

Fig. 5. Distance and traffic support capability diagram of 1.8 G

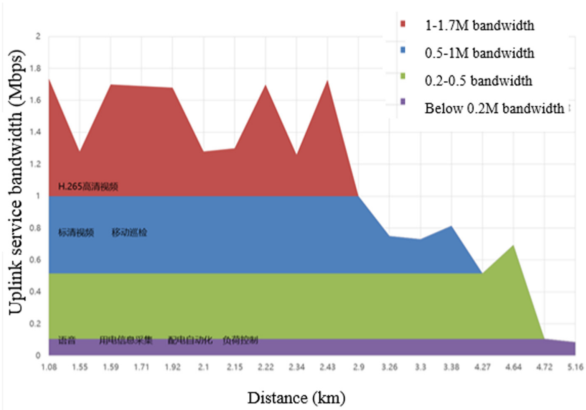

Fig. 6. Distance and business support capability diagram of 230 M

In addition, through theoretical simulation analysis, we can see that the minimum bandwidth of power wireless private network is 1.4 MHz under the condition of considering only the basic power services. When the information collection interval is reduced to 5 min, the minimum bandwidth is 3 MHz. The minimum bandwidth required is 5 MHz when high precision data transmission is required for distribution automation, and 10 MHz is the minimum bandwidth required to support other extended services, such as videoconferencing, emergency repair, etc.

5 Conclusion

On the basis of the basic principle of TD-LTE network structure, this paper analyzes the traffic model, and takes the actual case as the background, the technical parameters of 1.8 G and 230 M system are compared by data processing method and comparative analysis method. The theoretical analysis and test results verify the ability of power wireless private network to support power service. By comparing the technical parameters of 1.8 G and 230 M, the theoretical analysis and test results show that, in addition to being slightly superior to the former in terms of cell coverage radius, the 230 M system is much weaker than the 1.8 G system in terms of throughput, delay, service support capability and so on. The analysis and test provide technical support for the unified construction of power terminal communication access network and lay a solid foundation for the popularization and application of LTE power wireless private network.

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