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A Hybrid Networking Model for the Access Layer of the Communication Network for Distribution in Smart Grid

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Abstract: The access layer in the communication network for distribution is an important link in the automation of smart distribution power grid. In current access layer of communication network for distribution in Chinese power grid systems, several communication methods like optical fiber, medium-voltage carrier communication, 1.8GHz TD-LTE power private wireless network, 230MHz TD-LTE power private wireless network, public wireless network are constructed concurrently and running simultaneously in an identical power supply area. This traditional networking model will cause repeated construction and operation and maintenance difficulties in the communication network of power grid. On the basis of giving a detailed analysis of the radio link budget of TD-LTE power private wireless network in two frequencies, this paper present a multi-communication methods hybrid networking model, which gives a clear boundary for different communication methods based on the isoline with equal signal strength of the TD-LTE power private wireless network and accomplish the optimization of communication resources for distribution.

Keywords: multi-communication methods, communication network for distribution, TD-LTE power private wireless network

1. Introduction

The access layer in the communication network for distribution showed in Figure 1. is used in gather the data flow in the distribution automation equipment such as DTU(Distribution Terminal Unit) and FTU(Feeder Terminal Unit) and send it to the backbone layer in the communication network.

In current access layer of communication network for distribution in Chinese power grid systems, several communication methods like optical fiber(industrial switch or EPON), medium-voltage carrier communication, 1.8GHz TD-LTE power private wireless network, 230MHz TD-LTE power private wireless network, public wireless network[1] are constructed concurrently and running simultaneously in an identical power supply area. This traditional networking model will cause repeated construction and operation and maintenance difficulties in the communication network of power grid. The research of a new networking model is very necessary to solve these problems.

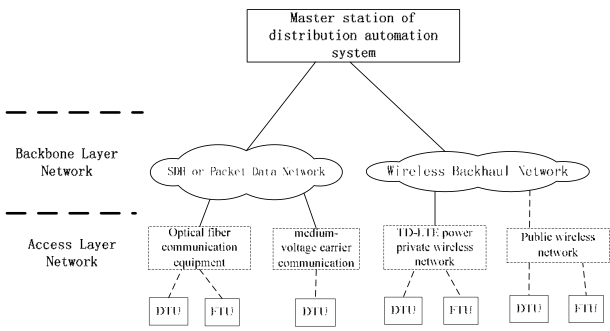

Figure 1. Several communication methods of the access layer in the communication network for distribution

2. Radio link budget of TD-LTE power private wireless network

Radio link budget is required before giving a clear boundary for wire communication and wireless communication. 1.8GHz TD-LTE power private wireless network and 230MHz TD-LTE power private wireless network is two mainstream technologies and different algorithms should be used in the radio link budget.

The Okumuram- Hata model[2] is used in the radio link budget of 230MHz TD-LTE power private wireless network. This model is established based on measured data, and is suitable for 150-1920MHz frequency. In different communication surroundings, the transmission loss can be calculated in following formula:

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L=69.55+26.16*lg(f)-13.82*lg(ht)–[(1.1*lg(f)-0.7)*hr-1.56*lg(f)+0.8] + [44.9-6.55*lg(ht)]*lg(d) + C (1)

urban area:C=0

suburb:C= -2* [lg(f/28)]2 -5.4

rural area:C=-4.78* lg(f)* lg(f)+18.33* lg(f)-40.98

fc:working frequency(MHz);ht:height of transmitting antenna(m);hr:height of receiving antenna (m);d:coverage range(km);C:Environmental compensation factor

Table 1. Radio link budget of 230 MHz TD-LTE power private wireless network

basic parameter			
Modulation Mode	QPSK	16QAM	64QAM
Base station/Terminal transmitted power(dBm)	37/23	37/23	37/23
Base station/Terminal antenna gain(dBi)	11.5/3.5	11.5/3.5	11.5/3.5
Thermal noise density (dBm/Hz)	-174	-174	-174
Receiver noise factor(dB)	6	6	6
Service bandwidth(KHz)	25	25	25
Receiver noise power(dBm)	-124.02	-124.02	-124.02
Cable loss(dB)	1	1	1
Okumuram- Hata model parameter			
System operating frequency (MHz)	230	230	230
Antenna height of base station/terminal(m)	45/1.5	45/1.5	45/1.5
Terminal antenna correction factor(dB)	-0.04	-0.04	-0.04
Distance factor	34.07	34.07	34.07
Constant factor	108.52	108.52	108.52
urban area / suburb / rural area			
Interference Margin (dB)	20/15/15	20/15/15	20/15/15
Service SNR(dB)	4	8	22
Receiver sensitivity (dBm)	-100/-105/-105	-96/-101/-101	-82/-87/-87
Maximum allowable transmission loss(dB)	137/142/142	133/138/138	119/124/124
Shadow fading loss (dB)	8.00	8.00	8.00
maximum allowable path loss (dB)	129/134/134	125/130/130	111/116/116
Environmental compensation factor	0/-7.07/-24.35	0/-7.07/-24.35	0/-7.07/-24.35

According to the radio link budget of 230MHz TD-LTE power private wireless network in Table 1. ,the coverage performance of single 230MHz TD-LTE base station in urban area / suburb / rural area can be calculated in Table 2.

Table 2. Coverage performance of single 230 MHz TD-LTE base station

Modulation / Environment	QPSK	16QAM	64QAM
urban area (km)	4.00	3.05	1.18
suburb (km)	9.04	6.90	2.68
rural area (km)	29.04	22.17	8.61

The radio link budget of 1.8GHz TD-LTE power private wireless network can be simulated in C0ST231-Hata model [3]. The coverage performance of single 1.8GHz TD-LTE base station can be derived by the C0ST231-Hata model path loss formula:

$$L = 46.3 + 33.9 \lg f - 13.82 \lg h_t - a(h_r) + (44.9 - 6.55 \lg h_t)(\lg d)^{\gamma} + C \qquad (2)$$

a(hr): correction factor of the height of receiving antenna

γ : Long distance transmission correction factor

It can be calculated from the path loss formula of Okumuram- Hata model and C0ST231-Hata model that in the same coverage environment, the 230 MHz TD-LTE base station will have a longer coverage distance in average and both the isoline with equal signal strength of 230 MHz frequency and 1.8GHz frequency will make logarithmic attenuation around the base station.

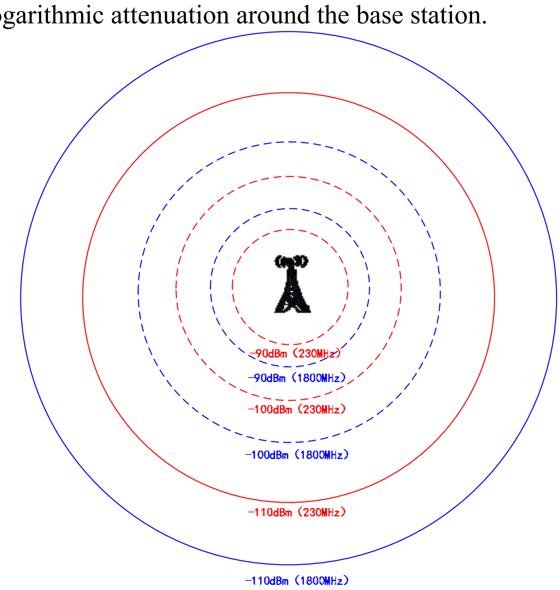

Figure 2. Isoline with equal signal strength of 230 MHz and 1.8GHz frequency

3. Hybrid networking model for the access layer of the communication network for distribution

This paper presents a hybrid networking model for the access layer of the communication network for distribution base on the signal attenuation characteristic of the 1.8GHz TD-LTE power private wireless network and 230MHz TD-LTE power private wireless network which is showed in Figure 3.

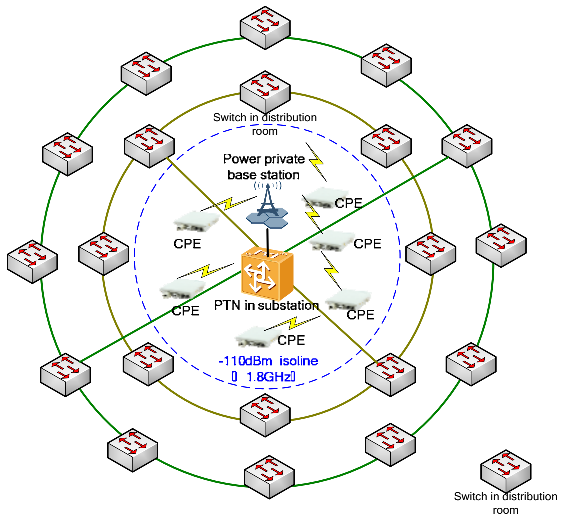

Figure 3. Hybrid networking model for the access layer of the communication network for distribution

Considering EPON network is hard to make adjustment after the construction is completed and medium-voltage carrier communication will cause non-planned power cut during operation and maintenance, this networking model choose industrial switch installed in the distribution room as the only wire communication method in the distribution communication network. The DTU in the distribution room can access the industrial switch by FE interface.

In this model, different communication methods will take the isoline with equal signal strength of the power private base station as the access boundary. Take 1.8GHz base station for example, all the DTU equipment in distribution room inside in coverage of the -110dBm isoline will access in power private wireless network by CPE(Customer Premises Equipment) terminal. Some distribution rooms in the coverage blind area of the TD-LTE power private wireless network where there is the sheltered architecture or in basement can access the public wireless network of telecom operators, and when condition allowed these distribution rooms can gradually access the TD-LTE power private wireless network by wireless repeater or other signal extension technologies. The power private base station will gather all the distribution automation data transmitted by the CPE and send it to the PTN or other backbone layer network equipment in the substation.

The industrial switches in the distribution room outside the -110dBm isoline make up several multiple hand-in-hand rings networks according to their geographic position. Each ring of industrial switches has at least two independent optical cable links to the backbone layer network. The equipment backbone layer network open up three –layer gateway to each ring of industrial switches in the access layer, and each ring of industrial switches opens up RSTP (Rapid Spanning Tree Protocol) to isolate the broadcast storm. Each industrial switch in a hand-in-hand ring has self-healing ability against single point of failure in optical cable based on RSTP

In this model, the ring networks of industrial switches are planned according to the signal test results of -110dBm isoline. The optical cables between the distribution rooms are planned after the construction of power private base station is finished according to the typical connection mode of power distribution.

4 Conclusions

TD-LTE power private wireless network has less construction cost than optical fiber communications and has higher safety characteristics than public wireless network. In the networking model presented in this paper, DTU equipment in the area around the power private base station access TD-LTE power private wireless network instead of optical fiber can make the construction model of optical cable change from plane to line, which reduces network construction cost as well as ensure reliability. Moreover, the DTU in the signal overlapping area of adjacent two power private base station access the hand-in-hand rings of industrial switches can avoid the unstable communication causing by frequent cell handover.

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