Research on Network Optimization and Network Security in Power Wireless Private Network

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Abstract. With the explosive growth of communication demand, all kinds of services require higher and higher wireless communication indicators, and the power wireless private network and 4G public network are not enough to support the massive connection, bandwidth access and low delay service requirements in the unit area, and can not support the development of the power internet of things. On the basis of this situation, this paper puts forward planning research of technologies in power system, analyzes the requirements of network in detail, and the coverage and capacity planning of network. As an important infrastructure to support the development of power system, the network will greatly promote the development of energy Internet strategy, and will greatly promote and upgrade the power services.

Keywords: TD-LTE · Network optimization · Network security · Wireless private network · Interferometric analysis · Coverage optimization

1 Introduction

After many years of construction, the State Grid has a good foundation in terms of site, communication network and so on [1–5], and has natural advantages in power access, which can provide strong basic resource support for 5G network. Aiming at this situation, this paper puts forward research on network planning in power system. The problem of optical fiber access or the high construction cost and long construction cycle of optical fiber will lead to the problem of service access. The wireless communication network is more suitable for the access of distributed terminals, especially to meet the communication needs of mobile terminals [6–10].

Coverage, capacity and quality of wireless communication network are the key factors. Network coverage, network capacity and network quality fundamentally reflect the service level of wireless network, and it is the part that needs to be improved in wireless network optimization. As we all know, network optimization is a complex, arduous and far-reaching work. As a new 4G technology, the content of TD-LTE network optimization has both similarities and differences with other standard systems.

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2 Analysis of Service Requirements

For wireless access networks, base stations are distributed and consist of BBU, RRU and antennas [9]. RRU and antenna are deployed in the power tower or the roof of its own property, and BBU of many stations are concentrated in the power communication room. Control services and other services of the power network are transmitted back to the core network through different physical ports of BBU and different wavelengths of transmission equipment.

As far as carrying network is concerned, the three-level structure of inter-provincial trunk line, provincial trunk line and metropolitan area network is adopted, in which the inter-provincial and provincial trunk lines adopt 100G OTN technology. The metropolitan area network is divided into core, convergence and access layers, in which the access layer uses 10G of equipment to network, and the convergence layer and core layer use 40G or 100G of equipment to network.

Core network, the use of regional and provincial deployment mode, in which control, signaling, management and other network elements in the company's six branches of the provincial company centralized deployment, user-face network elements in the provinces or prefectural companies deployment, and MEC equipment can be deployed according to needs of services.

As the technical means to support the operation and maintenance of the 5G network, the management support platform mainly realizes the functions of equipment management, business distribution, billing, user management, data statistics and analysis, and adopts the mode of centralized deployment.

For security protection, a unified, flexible and scalable network security architecture is built to meet the security requirements of different security levels for different applications [11]. A eSIM security chip is deployed on the terminal side to realize the security of terminal access. Wireless network and a host network itself do not perceive user data, through the air-port encryption, IPSec to achieve transmission security. The unified identity authentication management system is deployed on the core network side to realize the identity authentication of the whole chain. Deploy firewalls or security gateways on the network boundary side to ensure security on the Internet side. 5G network slicing software and hardware isolation to achieve security isolation between service streams.

3 Link Budget

The propagation model is used to predict the loss of radio waves on various complex propagation paths, which is the basis of mobile communication network. Whether the communication model is accurate or not is related to whether the district planning is reasonable and whether it can meet the needs of construction with more economical and reasonable investment [12].

The frequency range of communication mode in network is 0.5–6 Ghz, divided into two models, dense urban area, suburban area and rural area. The formula of propagation model in dense urban area is

$$P_L = 161.04 - 7.1 \lg w + 8.5 \lg h - (24.37 - 3.7h/h_{BS}^2) \lg h_{BS} + (43.32 - 3.1 \lg h_{BS})$$

$(\lg d_{3D} - 3) + 20 \lg f_C - [3.2(\lg 17.625)^2 - 4.97] - 0.6(h_{UT} - 1.5)$

For suburban and rural areas, the formula used for the propagation model is as follows

$$P_L = 161.04 - 7.1 \lg w + \lg h + 7.5 \lg h - (24.37 - 3.7h/h_{BS}^2) \lg h_{BS} + (43.32 - 3.1 \lg h_{BS})(\lg d_{3D} - 3) + 20 \lg f_C - [3.2(\lg 11.75h_{UT})^2 - 4.97]$$

PL is the propagation path loss in the formula, and the unit is the dB. h_{BS} is the actual height of the terminal equipment, and the unit is the meter [13]. f_C is central frequency, and the unit is GHz. d_{2D} is the ground horizontal distance between base station and terminal equipment, and the unit is the meter. d_{3D} is the space distance between base station and terminal equipment, and the unit is the meter. W is the width of the street, and the unit is the meter. h is the average height of the scene building, and the unit is the meter. The specific parameters are shown in Fig. 1.

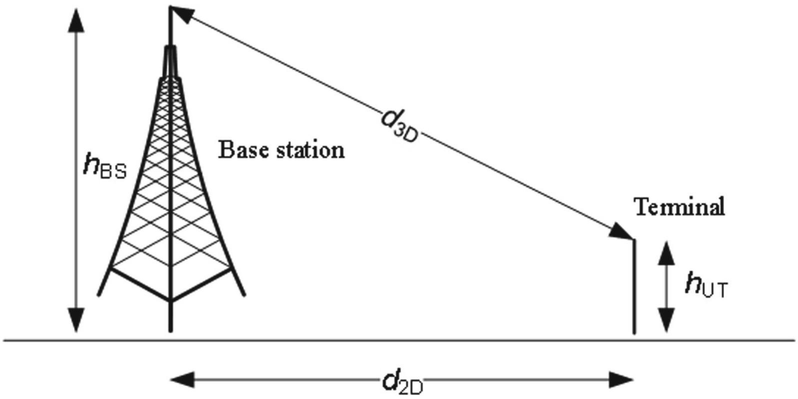

Fig. 1. Parameters of the propagation model

In the propagation model, the lower the frequency, the smaller the propagation loss, the farther the coverage distance, the stronger the diffraction ability, but the frequency resources in the low frequency band are tight and the system capacity is limited [14]. The higher the frequency, the greater the propagation loss, the closer the coverage, especially the worse the indoor coverage. The number of sites required for high frequency bands is much larger than that for low frequency bands. At the same time, the coverage is also affected by the height of building density, topography, vegetation distribution and so on. Appropriate increase in antenna height can reduce propagation loss. Through the analysis, the coverage radius of 5G in the 700 MHz frequency band of dense urban area, general urban area, suburb or rural area is shown in the following table (Table 1).

Table 1. Link budget

Parameter		Dense area		Urban area		Rural area	
		UL	DL	UL	DL	UL	DL
System	Rate of edge data	1M	10M	1M	10M	1M	10M
	Frequency (GHz)	0.7	0.7	0.7	0.7	0.7	0.7
	Bandwidth (MHz)	60	60	60	60	60	60
	Number of RB	21	63	21	63	21	63
	Bandwidth used (KHz)	7560	22680	7560	22680	7560	22680
Transmitter	Total transmit power (dBm)	23	53	23	53	23	53
	Single antenna transmission power (dBm)	23	50	23	50	23	50
	Actual transmit power (dBm)	14.13	63.90	14.13	63.90	14.13	63.90
	Multi-antenna gain (dB)	0	3	0	3	0	3
	RB required to allocate	21	63	21	63	21	63
	Height of transmitting antenna (hbs/m)	1.5	30	1.5	30	1.5	30
	Gain of transmitting antenna (dBi)	0	15	0	15	0	15
Receiver	SINR (dB)	−16	−16	−16	−16	−20	−20
	Noise coefficient of the receiver (dB)	2.3	7	2.3	7	2.3	7

(*continued*)

Table 1. (*continued*)

Parameter		Dense area		Urban area		Rural area	
		UL	DL	UL	DL	UL	DL
	Sensitivity of the receiver (dB)	−136.81	−109.34	−136.81	−109.34	−140.81	−113.34
	Height of receiving antenna (hut/m)	30	1.5	30	1.5	30	1.5
	Diversity gain of the receiver (dB)	3	0	3	0	3	0
	Gain of receiving antenna (dBi)	15	0	15	0	15	0
Other gains and margins	Edge coverage (%)	82.5	82.5	82.5	82.5	82.5	82.5
	Shadow fading standard deviation (dB)	8	8	6	6	4	4
	Shadow fading margin (dB)	7.48	7.48	5.61	5.61	3.74	3.74
	Penetration loss (dB)	15	15	10	10	7	7
	Human losses (dB)	0	0	0	0	0	0
	Interference allowance (dB)	1.5	1.5	1.5	1.5	1.5	1.5
	Feeder losses (dB)	0.5	0.5	0.5	0.5	0.5	0.5
	Switching Gain (dB)	0	0	0	0	0	0
	Fast fading margin (dB)	0	0	0	0	0	0

(*continued*)

Table 1. (*continued*)

Parameter		Dense area		Urban area		Rural area	
		UL	DL	UL	DL	UL	DL
Scene	The width of the street (W/m)	20	20	15	15	8	8
	Average height of buildings (h)	30	30	25	25	10	10
Maximum path loss (dB)		126.46	148.76	133.33	155.63	142.2	164.5
Coverage (m)		848	3181	1382	5187	3006	11282

4 Coverage Simulation

Adopt 700 MHz frequency band, select urban political and economic center area, rural area as simulation verification area [15] (Fig. 2).

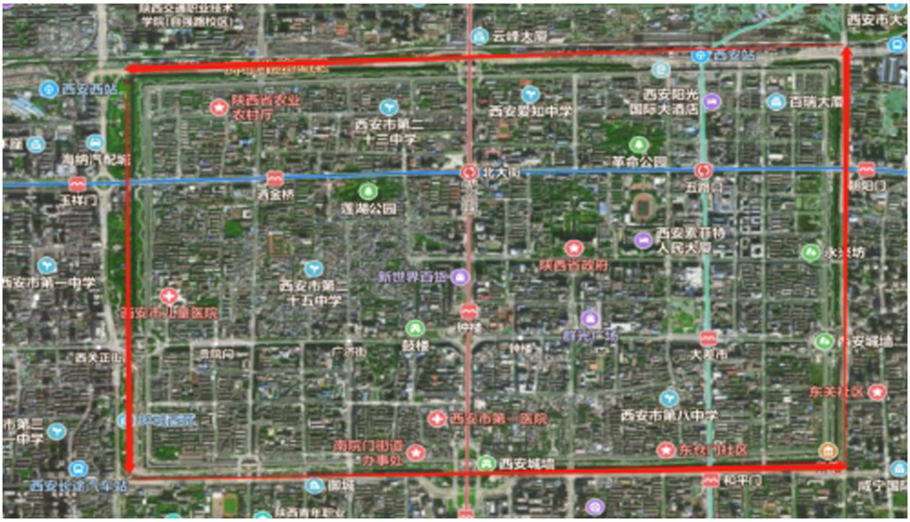

Fig. 2. Schematic representation of simulation areas in dense urban areas

4.1 Dense Urban Areas

Using frequency band of 700 MHz and using network planning simulation software to carry out iterative simulation, 7 stations are planned, the radius of single station coverage is about 850 m, and the station distance between each other is about 1.4 km. The simulation results are shown below (Fig. 3).

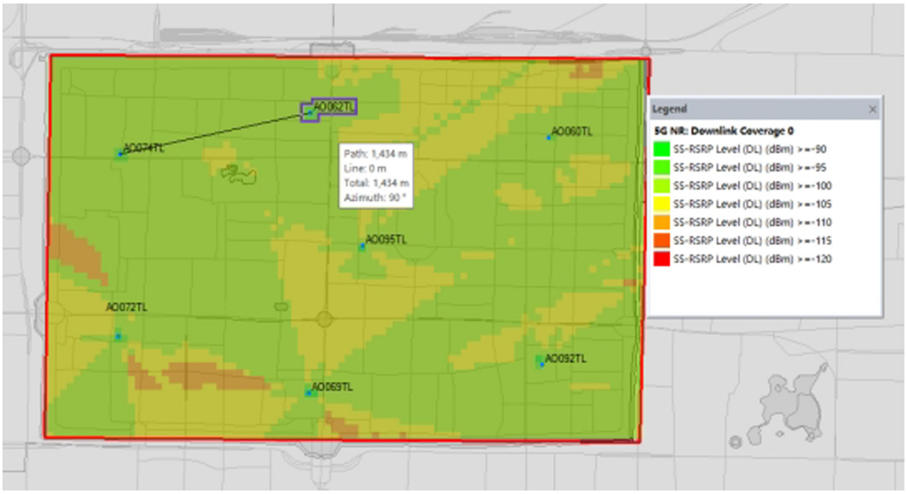

Fig. 3. Coverage simulation diagram of dense urban area

Statistics on signal coverage are shown in the table below (Table 2).

Table 2. Statistical table of signal coverage in dense urban areas

Name	Arae (km^2)	Percentage of coverage %
Coverage Forecast (700 M) Intensive Urban Areas	12.181	100
RSRP $> = -90$	0.013	0.107
RSRP $> = -95$	0.047	0.388
RSRP $> = -100$	8.515	70.372
RSRP $> = -105$	11.775	97.314
RSRP $> = -110$	12.1	100
RSRP) $> = -115$	12.1	100
RSRP $> = -120$	12.1	100

4.2 Urban Areas

The simulation area in the county is 10.14 km^2, as shown in Fig. 4.

By using the network planning simulation software, the schematic diagram of the simulation area in the general urban area adopts 700 MHz frequency band, and the iterative simulation is carried out. Four stations are planned, the station distance is about 1800 m, and the coverage radius of single station is about 1300 m. The simulation results are shown in Fig. 5.

Fig. 4. Schematic illustration of the simulation area in general urban area

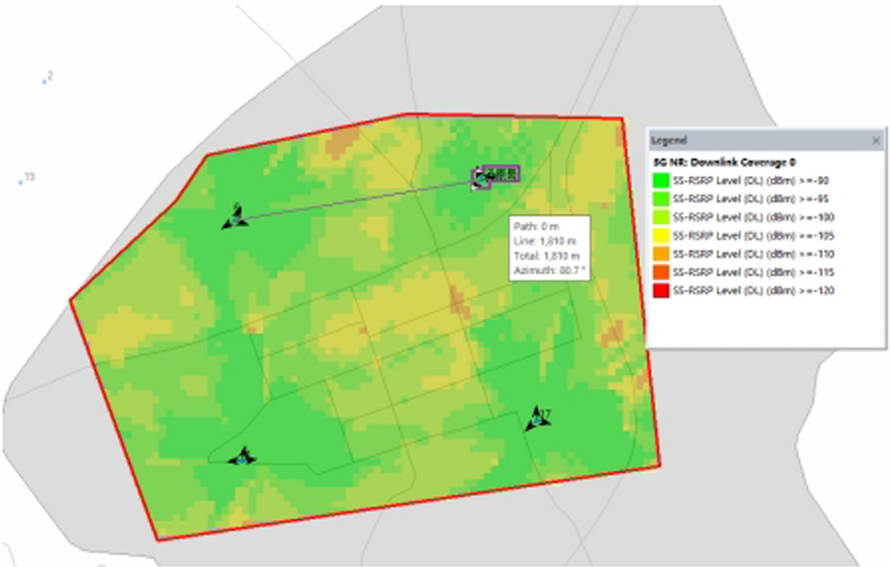

Fig. 5. Schematic illustration of simulated coverage in general urban areas

Statistics on signal coverage are shown in the table below (Table 3).

Table 3. Statistical table of signal coverage in general urban areas

Name	Arae (km^2)	Percentage of coverage %
Coverage Forecast (700 M)	10.165	100
RSRP > = −90	2.793	27.477
RSRP > = −95	5.685	55.927
RSRP > = −100	8.678	85.371
RSRP > = −105	10.05	98.869
RSRP > = −110	10.165	100
RSRP) > = −115	10.165	100
RSRP > = −120	10.165	100

4.3 Suburban and Rural Areas

The simulation area is 12.07 square kilometers, as shown in Fig. 6.

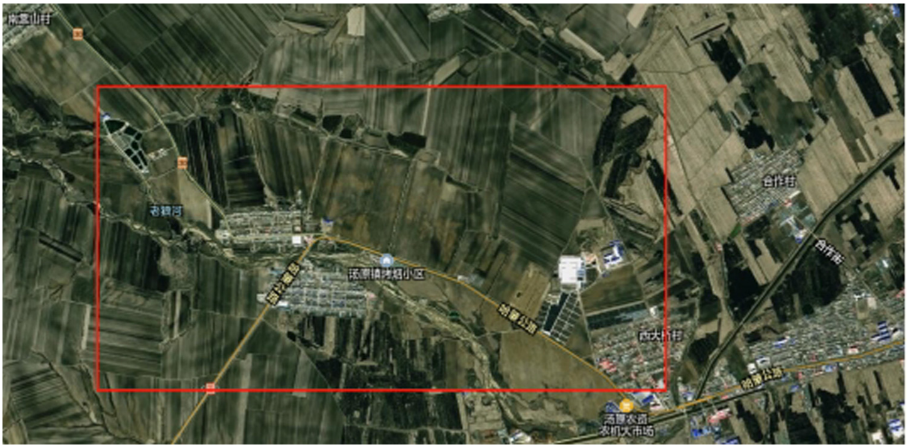

Fig. 6. Schematic representation of simulation areas in suburbs and rural areas

By using 700 m frequency band, the network planning simulation software is used to carry out iterative simulation, one station is planned, and the coverage radius of one station is about 3000 m. The simulation results are shown below (Fig. 7).

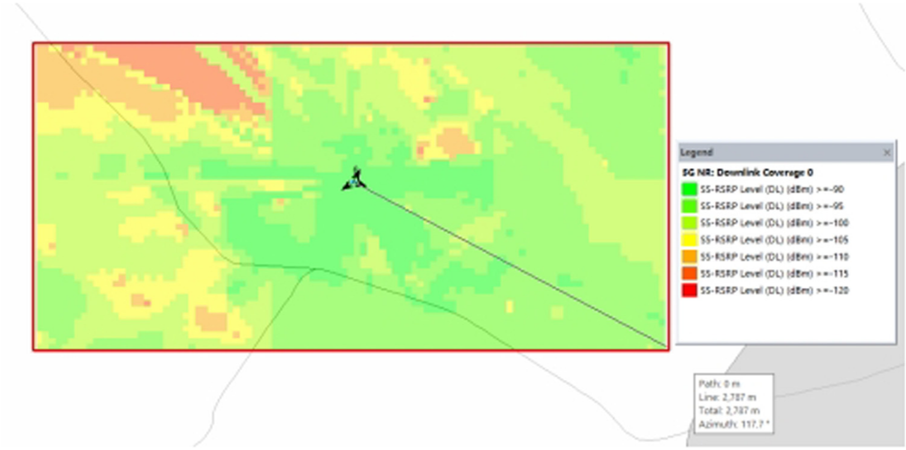

Fig. 7. Schematic diagram of coverage simulation in suburban and rural areas

Statistics on signal coverage are shown in the table below.

Name	Arae (km^2)	Percentage of coverage %
Coverage Forecast (700M)	12.073	100
RSRP > = −90	1.493	12.567
RSRP > = −95	6.367	53.594
RSRP > = −100	9.76	82.155
RSRP > = −105	10.953	92.197
RSRP > = −110	11.508	96.869
RSRP) > = −115	11.88	100
RSRP > = −120	11.88	100

Compared with the link budget, the coverage radius is basically the same as that of the link budget.

5 Capacity Planning

Based on experience, the simulation is divided into four different scenarios,core-intensive area, business-intensive area, business-based area and business-dispersing area. The simulation results of the business model in the core dense area are shown in the following table (Table 4).

Table 4. Service model simulation estimation in dense areas

Type of service	Name	Bandwidth (bps)	Terminal density (/km^2)	Prediction of integrated capacity (Mbps/km^2)
Basic service	Two shakes of electric power	2.4 k	71.04	0.01332
	Threeshakes of electric power	19.2 k	23.68	0.03552
	Electricity information collection	560 k	3000	65.625
	Load control instructions	2.5 k	23.68	0.004625
	Charging station - Data acquisition	4 k	1	0.0003125
	Distributed power	4 k	23.68	0.0074
	Remote metering	1.13 M	2	0.18078125
	Remote signalling	1.13 M	2	0.18078125
Activate service	Charging station - Image acquisition	1 M	1	0.08
	Charging station - Video capture	1 M	1	0.08
	Transmission line monitoring	1 Mbps	0.2	0.016
	Data collection	18.5 k	0.5	0.000722656
	Image acquisition	1 M	0.5	0.04
	Video capture	1 M	0.5	0.04
	Transmission and distribution operations	1 M	0.2	0.0016
	Manual inspection - Voice	64 k	0.1	0.0005
	Manual inspection - Video	1 M	0.1	0.008
	Manual inspection - Data	1 Ms	0.1	0.008

(*continued*)

Table 4. (*continued*)

Type of service	Name	Bandwidth (bps)	Terminal density (/km^2)	Prediction of integrated capacity (Mbps/km^2)
	Transmission and distribution machine inspection	1 M	1	0.08
	Power quality monitoring	1 M	20	1.6
	Smart home	1 M	2000	16
	Smart busines	1 M	0.2	0.016
	Mobile Office - Voice	64 k	100	0.05
	Mobile Office - Video	2 M	100	0.8
	Mobile Office - Data	1 M	100	0.8
	Video surveillance - Ultra Clea	20 M	48	7.68
	Smart jobs - Data	1 M	1	0.08
	Smart Jobs - Video	1 Mbps	1	0.08
	Smart jobs - Voice	64 k	1	0.0005
	Deepening application of intelligent meter	7 k	3000	0.01640625
	Distributed energy storage	1 M	100	0.08
	Intelligent distribution terminal	1 M	30	0.024
Total				11.7 MB/km^2

The service model estimates for the three regions are shown in the table below (Table 5).

Table 5. Service model measurement tables for various scenarios

Type of area	Capacity demand forecasting
Core dense areas	11.7 MB/km^2
Core dense areas	2.41 MB/km^2
Operational base are	0.1 MB/km^2
Decentralized area	0.01 Mbps/km

Under the definition of 3GPP, three different types of services will emerge in the next 5G in the future, that is eMBB, mMTC and uRLLC. eMBB service requires high rate, mMTC service requires high connection number and power consumption standby, and uRLLC service requires high delay and reliability.

The following is a simple calculation of the capacity of a single station and the whole network.

The system with 30 M bandwidth has 156 resource blocks, 30 kHz subcarriers 12 subcarriers, and the spectrum utilization is 93.6%.

Modulation mode is 256QAM, downlink support 4 streams, peak throughput of single cell is as follows

$$30 \times 8 \times (948/1024) \times (12/14) \times 4 = 0.75\,\text{Gbps}$$

Modulation mode is 256QAM, uplink support 2 stream, peak throughput of single cell is as follows

$$30 \times 8 \times (948/1024) \times (12/14) \times 2 = 0.375\,\text{Gbps}$$

From the above analysis, we can see that the current configuration of base station can meet the needs of the services.

6 Conclusion

Driven by the construction of power Internet of things, the services of power grid stock needs to be optimized and upgraded, the emerging services is booming, the requirement of the network security is higher and higher, and all kinds of services require higher and higher wireless communication index. Network with low delay, large connection and large bandwidth fundamentally meets all kinds of requirements and in the construction and development of the power Internet of things, and forms a new form of power network. This paper analyzes the requirements of network and the coverage and capacity planning of network in detail. As an important infrastructure to support the development of power system, the construction of network will greatly promote the development of energy Internet strategy, and will greatly promote and all links of service in power system.

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