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Research on CIoT Planning and Deployment

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***Abstract*—In order to plan the Cognitive Internet of Things (CIoT) reasonably, this paper put forward the planning ideas combining with the characteristics of technology and the trend of evolution. After analyzing the links such as rate, index and frequency planning, relevant suggestion to the deployment strategy of CIoT was put forward.**

***Index Terms*—CIoT, NB-IoT, planning index, frequency planning.**

I. Introduction

In the contemporary era of "Internet of Everything", the business scale of IoT(Internet of Things) in China is still small, mainly using 2G networks to provide access pipelines and partially using 4G networks [1]-[2]. IoT services can be classified by speed into three categories: high, medium and low. In the future, the expected wide-area, low-power, low-mobility (LPWA,Low Power Wide Area) business of IoT is currently focused on access technologies such as NB-Iot, LoRa, Sigfox and Zigbee [3].

Currently, services of IoT carried on the network of 2/3/4G include the following problems: high terminal power consumption and poor 2G terminal standby capability; network of 2/3G can't meet the application requirements of massive terminals; typical network scenarios include insufficient coverage of indoor wireless Meter reading, environmental monitoring in remote areas and monitoring of underground resources; terminal types, small quantities, high development threshold, high cost of telecommunication modules, high overall cost [4].

There are a variety of optimization techniques, including cellular and non-cellular two categories to carry on IoT. The cellular technologies represented by NB-IoT (Narrow Band Internet of Things) and eMTC have been more optimized for the requirements of IoT, and has been widely concerned by telecommunication operators [5]-[7]. However, non-cellular technologies represented by LoRa and Sigfox are not suitable for operators to deploy on the entire network because of uncontrollable outdoor interference of unlicensed spectrum, optimization of contiguous network, and performance of the network to be verified.

In this paper, the planning principles of CIoT are proposed, and the relevant indexes and frequencies of planning are analyzed and studied in detail. Related suggestions on planning and deployment are put forward at last.

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II. Development Trends and Contacts of The Network

A. Multi-network Positioning and Evolution

Before the advent of the 5th Generation of mobile telecommunication, it is the development trend of telecommunications networks that reassign the frequencies of 2G network, promote the evolution of 2G networks to FDD network and the preserve 2G network as thin as possible for long-term [8]. The 3G network will be completed to withdraw from the network in 2017, the frequencies of 3G network will be reassigned to TD-LTE system. 4G network which including FDD LTE and TD-LTE, will become an efficient network with both data and voice capabilities [9]. When we are planning network, we must comprehensively consider 2G, LTE FDD and NB-IoT construction on 900MHz band.

B. Planning Ideas of NB-IoT

The NB-IoT and LTE FDD 900M are essentially the same network because of sharing the same hardware equipments. The planning of NB-IoT is actually the planning of the LTE FDD 900M network. The built NB base station can support the LTE FDD network in the future by simply enabling software functions. Considering the development of LTE FDD, the two networks can be joint planning. It is mainly based on LTE FDD planning [10]. NB-IoT coverage can be achieved by LTE FDD planning base stations.

Planning idea one: theoretical station spacing is calculated according to the highest coverage level 3 (MCL = 164dB) of NB-IoT and meet the requirement of continuous coverage of penetrating 3 walls. Site planning tools are used to choose from the FDD base station library (1: N, N is about 4).

Planning idea two: if the sites of NB-IoT are the same with those of LTE FDD, we can find that the signal of NB-IoT penetrate 2-3 more walls to LTE FDD according to the highest coverage level 3

It is recommended that construction of NB-IoT be planned according to the idea one in the early stage. Later, as data service grow, sites are encrypted in areas with high service demands to meet higher capacity and speed requirements until the scale of NB-IoT and FDD base stations reaches 1: 1.

III. Planning of NB-IoT

A. Positioning of LTE FDD

LTE FDD network can be used on 900M band, 1800M band and indoor coverage. LTE FDD 900MHz network can be used as the main 4G underlying network coverage, continuous coverage. Therefore, the low-frequency LTE FDD air interface is expected to exist for a long time. However, the network level at 900 MHz is expected to surpass the 2G network level to fully carry the 2G voice service and make up the dual-layer short board of TD-LTE.

LTE FDD 1800M can be used as a hotspot area capacity supplement means to enhance the uplink capacity to make up for TD-LTE network uplink network capacity problems. the E-band heterogeneous network will be used to avoid interference when the low-frequency advantage of LTE FDD is no longer obvious in the buildings. In the lack of capacity, weak coverage and other scenarios, you can try to use 1800MHz as a supplementary means of coverage [11].

B. Service Type and Rate

Based on the definition of QoS index of 3GPP protocol, VoLTE video calling service has higher requirements on uplink speed. Streaming media programs, medium and high speed Internet access, and video monitoring services are mainly required for downlink speed. VoLTE services require symmetric and high uplink rates between 50 Kbps and 2176 Kbps. However, services such as streaming media programs, medium and high speed Internet access and video surveillance services generally require downlink rates between 64 Kbps and 5 Mbps. Based on the service conditions of domestic and overseas operators, it is proposed to set the service index of LTE FDD as 95% Coverage Probability in Urban Area, 4 Mbps in Downstream Edge, and 1Mbps in Upstream Edge [12]. The downlink rate requires to meet the 720p/30fps frame resolution requirements, uplink to meet the VGA15 frame resolution requirements.

C. Sub-scene Planning Index

Determining scientific planning index is the core content of network coverage planning. Exploring the process of determining the planning index, that is, defining the technical targets of the network construction, wireless environment and network load, conducting the link budget and limited channel analysis, specifying the requirements of the test index, calculating the station spacing, and simulating the process [13].

Link budget of NB-IoT is shown as below:

$$MAPL_{UL} = P_{out\_Module} - L_{OTA\_UE} - L_{shell\_UE} - L_p - M_f - M_I + G_{a\_BS} - L_{f\_BS} - S_{BS} \quad (1)$$

$MAPL_{UL}$: Uplink maximum propagation loss;

P_{out_Module}: Terminal module maximum transmit power;

L_{OTA_UE}: Terminal OTA loss (dB), due to NB-IoT terminal diversity is large, the measured value of large differences;

L_{shell_UE}: Terminal shell loss;

L_p: Building penetration loss (dB), which is larger than that of an ordinary LTE network, here consider penetrating;

M_f: Slow fading margin (dB), which is related to propagation environment and coverage probability;

G_{a_BS}: Base station antenna gain;

L_{f_BS}: Feeder loss;

S_{BS}: The sensitivity base station receives (dBm), when MCL = 164dB, sensitivity is-141dBm.

Based on the planning ideas mentioned above, the LTE FDD coverage index and station spacing requirements, and the link budget, the planning station spacing recommendations for NB-IoT base stations and the NRSRP requirements are proposed, as shown in Table 1.

The planning index of the CIoT should be determined by theoretical calculation and actual measurement verification after the key technical index of NB-IoT base station and terminal, such as receiving sensitivity, terminal OTA loss and minimum SINR requirements be determined by all parties. The current planning index may be changed after the conditions are clear.

According to the requirements of station spacing in Table 1, the planning and simulation of main city of high penetration in 5 different regions of China were conducted. Simulation results verify the rationality of planning index, as shown in Table 2.

At the same time, we selected the continuous coverage verification of 30 BTSs in two main scenes of main city of high penetration and general urban area of a certain city in eastern China, basically in line with the planning expectation. The test results are shown in Table 3.

D. Frequency Planning of CIoT

It includes 2G frequency reassigning, frequency strategy, frequency point planning as follows:

1) Frequency Reassigning

Taking China Mobile as an example, since June 2015, the traffic carried on the 2G network has remained steady while the data traffic has dropped. At the same time, the network utilization rate has been declining slowly. As a result, it is possible that some 2G network frequency can be reassigned. Under the condition of ensuring the voice service, based on the data of the current network, the forecast of the service and the use of frequency resources, the actual demand frequency bandwidth of the 2G network can be predicted and analyzed in the planning period, and the bandwidth that can be reassigned will be calculated finally.

It is divided to sub-short-term and long-term implementation for frequency retreating. For 900MHz band, 5M frequency retreating will be implemented in urban areas in 2017 according to business conditions and 10M frequency cutback will be implemented in rural areas. After 2018, 10M urban frequency and 15M rural frequency retreating will be implemented. For the 1800MHz band, the conditions for the urban area to retreat 15M and the rural area to recede to 20M have been recently proposed, but it is still suggested to use for GSM network, and to use for LTE FDD networking in the future. In addition, taking into account the 3G traffic back to the GSM network caused by 3G network cancellation, it should give priority to retreat 2G frequency in rural areas [14].

2) Frequency Strategy

Frequency strategy of NB-IoT: three frequency networking modes about NB-IoT were proposed during 3GPP RAN1 # 83 Conference, November 2015: Stand-alone, Guard band, In band mode. There are some advantages of stand-alone mode that high downlink transmit power, best downlink coverage performance, rate, delay, power consumption, therefore, it was basically chosen stand-alone mode by Chinese telecommunication operators.

In stand-alone mode, if NB adopts 1:1 networking, 100 kb protection bandwidth is required between GSM and NB, and no protection band is required between LTE and NB (LTE built-in guard band). If NB adopts 1: 4 networking, 200kb protection bandwidth is required between GSM and NB. It is required to ensure that the GSM frequency point cell with the NB frequency interval of 200kb and the NB station are same. If the bandwidth between LTE and NB is more than 5MHz, there is a LTE built-in guard band. If it is less than 5MHz, there must be 100kb protection bandwidth [15].

Frequency strategy of eMTC: the same frequency band is used by eMTC and LTE system, if TD eMTC is upgraded based on the existing TD-LTE, the frequency band of TD-LTE is adopted and the frequency F is preferably selected as the outdoor coverage. If FDD eMTC is constructed synchronously with LTE FDD (900MHz), LTE FDD frequency band is adopted, 900MHz is preferable as the outdoor coverage.

3) Frequency Point Planning

In the stand-alone mode of NB frequency planning, we must take into account frequency arrangements of 2G, LTE FDD and NB-IoT at 900MHz band. For example, China Mobile has reserved three high frequency points for NB-IoT, namely 953.4MHz, 953.6MHz, 953.8MHz. If FDD license is available in the future for China Mobile, it is recommended to deploy FDD at 948.3MHz (945.8MHz, 950.8MHz) with the GSM frequency reassignment of 5MHz; and at 948.3MHz(943.3MHz, 953.3MHz) with the GSM frequency reassignment of 10MHz; if reassign 15MHz, 10MHz +5 MHz will be used, 948.3MHz is the center frequency of 10MHz, 941.1MHz is the center frequency of 5MHz; if reassign 20MHz, 10MHz +10 MHz will be used, 948.3MHz is the center frequency points are 948.3MHz and 939MHz; The eMTC (FDD 900MHz) adopts the same scheme with the GSM frequency reassignment of 5MHz. At the initial stage of NB-IoT network construction, only one frequency is used by the method of the same-frequency network first to reserve the frequency for the inter-frequency network. If 900MHz network interference is severe and cannot be excluded after the network begins, it can be adjusted to different frequency. Multi-carriers will be considered after the business growth.

TABLE 1
NB-IOT BASE STATION TEST LEVEL REQUIREMENTS AND STATION SPACING RECOMMENDATIONS (95% PROBABILITY)

Area	NRSRP (dB)	SINR	Theoretical station spacing (m)	Planning range of station spacing (m)
Main city of high penetration loss	-83.7	-3	841	700-850
Main city of low penetration loss	-86.7	-3	1021	850-1050
General Urban	-86.7	-3	1238	1050-1300
County and Town	-88.7	-3	1511	1300-1600

TABLE 2
5 CITIES WEARING HIGH WEAR MAIN CITY SIMULATION INDEX

City	High penetration area of main city/ km^2	Number of NB-IoT base station	Average station spacing of NB-IoT/m	NRSRP compliance ratio/%
City1	186.6	280	868	95.1
City2	124.8	203	830	95.3
City3	158.2	293	794	95.4
City4	144.7	252	812	95.2
City5	211.5	360	835	95.0

TABLE 3
NB-IOT SUB-SCENE NETWORK AUTHENTICATION

Area	NRSRP Expected (5%Edge)/dBm	NRSRP test value (5% edge)/dBm	NRSRP test value (50%cumulative)/dBm	NRSRP test value (average)/dBm
Main city of high penetration (average station spacing of about 760meters)	-93.6	-90.3	-73.2	-73.1
General urban area (average station spacing of about	-97.2	-90.1	-71.8	-71.6

1060meters)

IV. Deployment strategy of CIoT

The coverage capability of NB-IoT is enhanced by 20dB + than that of GPRS coverage. If NB-IoT sites are same with GSM, it is predicted that coverage of NB-IoT should be be better than that of GSM.

According to the industry maturity, it is recommended to deploy NB-IoT 900MHz first, adopt Stand-alone mode and reserve eMTC capability at the same time to make it possible to start according to business development needs and industry maturity. For the future wireless network architecture, from start to finish, take into account joint planning construction of NB-IoT with FDD 900M. There is a same target between NB-IoT and FDD 900M. Because different frequency network of GSM and current network frequency band of TD-LTE are different from FDD 900M, so can't be based on GSM or TD-LTE current network to plan FDD network simply, it should be based on GSM + TDD total sites to plan FDD network to ensure that the network structure is reasonable.

In the initial stage of NB-IoT construction, the target is to form an outdoor continuous coverage network quickly and configure a single-cell capacity of 1 carrier. This is the 1: N networking for NB-IoT and LTE FDD base stations (N equals about 4). We can encrypt the site later based on clear service needs, and expanse single-cell capacity to 2 carriers on demand. If NB-IoT sites reach 1: 1 with LTE FDD sites, the signal coverage levels of NB-IoT will increase by about 10.8 dB, further enhancing the depth of coverage or boosting capacity.

V. Conclusion

The CIoT is of great significance to realizing the interconnection of all things and accelerating the upgrading of the information industry. In this paper, a brief analysis of the planning and deployment of CIoT is proposed. It is proposed that NB-IoT be deployed in stand-alone mode and in a low frequency intra-frequency network. Following the principle of joint planning of NB-IoT and LTE FDD, the paper proposes a deployment strategy of 1: N networking in the initial stage of NB-IoT and encryption on the basis of LTE FDD target sites later. It provides suggestions for planning and deployment of NB-IoT.

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