SPECTRUM BANDWIDTH REQUIREMENT FOR IMT SERVICES

IN CHINA BY 2020

China Academy of Telecommunication Research of MIIT

2013.01

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1. Introduction

Radio frequency is the foundation of mobile communication systems. In recent years China has experienced extraordinary development of IMT system especially for data traffic explosion, which results in increasingly high requirement for radio frequency spectrums and the current spectrum might hardly meet the future need.

This report estimates the future spectrum requirement for the International Mobile Telecommunications (IMT) as defined by the ITU in China by 2020. The overall objective of the study is to forecast the amount of spectrum bandwidth required for IMT services considering different geographic types. Besides, some preliminary consideration on suitable frequency ranges identified by the spectrum characteristics will be given.

2. IMT Development in China

Before introducing our estimation of spectrum bandwidth required for IMT service by 2020, it is necessary to know about the status and / or future trend of spectrum allocation and usage, market, network and other relevant information on IMT service development in China.

2.1 Spectrum Allocation and Usage

2.1.1 Spectrum Allocation for IMT

According to Radio Regulations of ITU and Regulations on Radio Frequency Allocation of People's Republic of China, 687 MHz frequency has been allocated for IMT system so far, as shown in Table 2-1.

Table 2-1 Spectrum Allocation for IMT in China

Duplex Mode			**lower Bound (MHz)**	**Upper Bound (MHz)**	**Bandwidth (MHz)**	**Sum-up (MHz)**
2G	FDD	UL	889	915	26	162
		DL	934	960	26	
		UL	1710	1755	45	
		DL	1805	1850	45	
		UL	825	835	10	
		DL	870	880	10	
3G	TDD	Un-paired	1880	1920	40	155
		Un-paired	2010	2025	15	
		Un-paired Indoor	2300	2400	100	
	FDD	UL	1920	1980	60	180

Duplex Mode			lower Bound (MHz)	Upper Bound (MHz)	Bandwidth (MHz)	Sum-up (MHz)
		DL	2110	2170	60	
		UL	1755	1785	30	
		DL	1850	1880	30	
LTE	TDD	Un-paired	2500	2690	190	190
Sum-up (MHz)						**687**

2.1.2 IMT Spectrum Utilisation Status

Totally 327 MHz spectrum has been assigned to operators providing 2G/3G services currently in China.

Table 2-2 Frequency Assigned to Operators

Frequency bands	Currently Assigned to Operators
UL: 825 MHz ~ 835 MHz DL: 870 MHZ ~ 880 MHz	CDMA2000/EV-DO (China Telecom)
UL: 889 MHz ~ 909 MHz DL: 934 MHZ ~ 954 MHz	GSM (China Mobile)
UL: 909MHz~915MHz DL: 954MHz~960MHz	GSM (China Unicom)
UL: 1710MHz~1735MHz DL: 1805MHz~1830MHz	GSM (China Mobile)
UL: 1735MHz ~ 1755MHz DL: 1830MHZ ~1850MHz	GSM (China Unicom)
TDD:1880MHz~1900MHz, 2010MHz ~ 2025 MHz	TD-SCDMA (China Mobile)
TDD: 1900MHz~1920MHz	TD-SCDMA (China Mobile)/PHS
UL: 1920MHz ~ 1935MHz DL: 2110MHz~2025MHz	IMT/ China Telecom
UL: 1940MHz ~ 1955MHz DL: 2130 MHz ~ 2145MHz	WCDMA (China Unicom)
TDD:2320MHz~2370MHz	TD-SCDMA(China Mobile) In-door only

In addition, another 50 MHz (2570~2620MHz) spectrum is now used for TD-LTE Trial by China Mobile.

2.2 Subscription

Mobile subscribers in China have maintained rapid growth and the increase in 3G users keeps steady. According to Figure 2-1, in the first three quarters of 2012 the cumulative growth in mobile subscribers of China was calculated 98.5 million. One interesting trend can be noticed that, in general, March and September were the two with highest additions while July always witnessed a trough.

Consequently the total number of mobile subscribers in China reached 1,085 million by the end of September, 2012. Meanwhile mobile service created 589.4 billion Yuan income during the 9 months, which was increased by 4% in the same period of 2011.

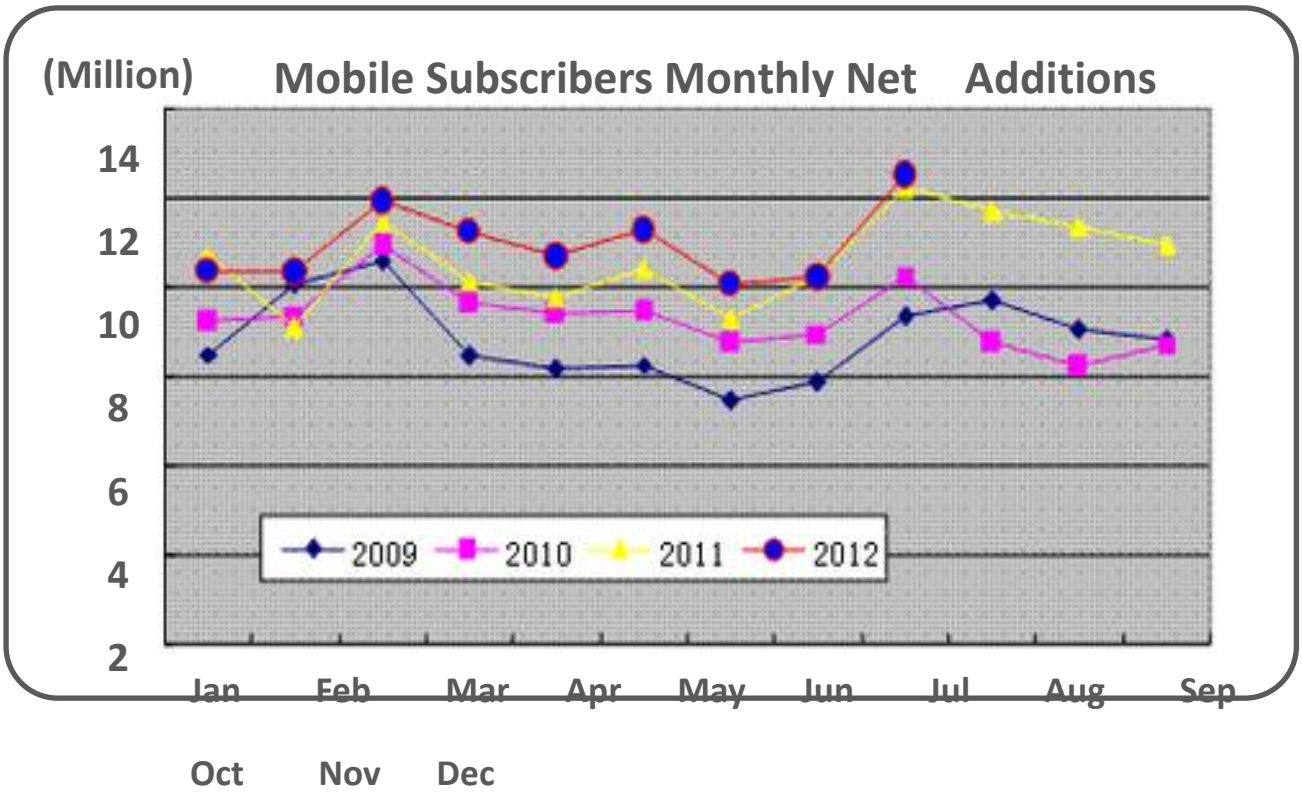


Figure 2-1 Mobile Subscribers Monthly Net Additions[1]

Through three and a half years development 3G industry in China has come into a benign stage and 3G market is accelerating. By September 2012 the total number of 3G Subscribers was over 202 million with penetration rate of over 18%.

There are three mobile service operators in China, China Mobile, China Telecom and China Unicom each operating TD-SCDMA, CDMA-2000 and WCDMA of 3G services respectively. And currently it is approximately in balance of the 3G market of the three operators, seeing Figure 2-2 below.

[1] Source: Ministry of Industry and Information Technology of the People's Republic of China (MIIT)

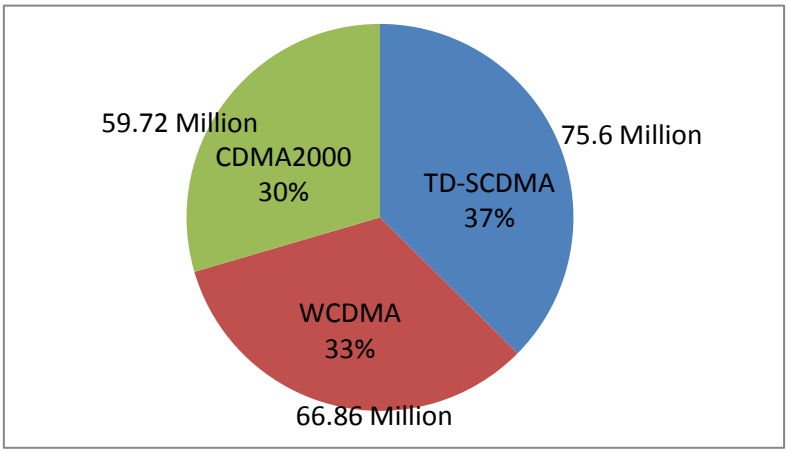


Figure 2-2 3G Subscribers Distribution in 3 Operators in China[2]

According to CATR's study, 3G service will become more and more popular in China in the near future. It is estimated that by the end of 2014 the number of 3G subscribers would reach 514.6 million with 3G penetration rate of over 40%.

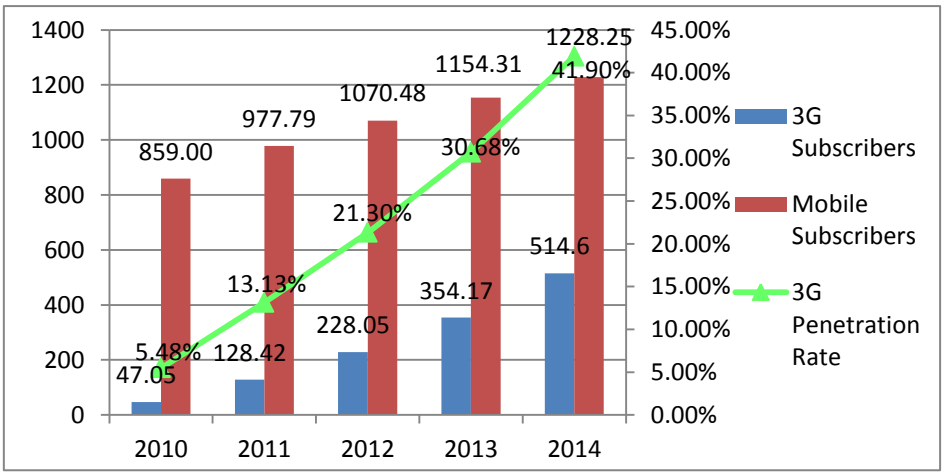


Figure 2-3 Estimation of Mobile Subscriptions Growth in China by 2014 (Million)[3]

2.3 Network

With 2009-2011 large scale 3G deployment, 3G network constructions have made interim success in China. According to Figure 2-4, by June 2012 the number of 3G base stations reached 859 thousand and China Unicom has the largest 3G network.

As for network enhancement, China Unicom is enlarging its HSPA+ network deployment in 56 cities with downlink peak-rate of 21 Mbps. Meanwhile outfield testing of dual-carrier HSPA+ is on-going in 5 cities including Guangzhou, Zhuhai, Shenzhen, Shijiazhuang and Tianjin to well prepare for the next stage of enhanced network commercialisation.

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[2] Source: Monthly Reports of China Mobile, China Telecom and China Unicom.

[3] Source: CATR

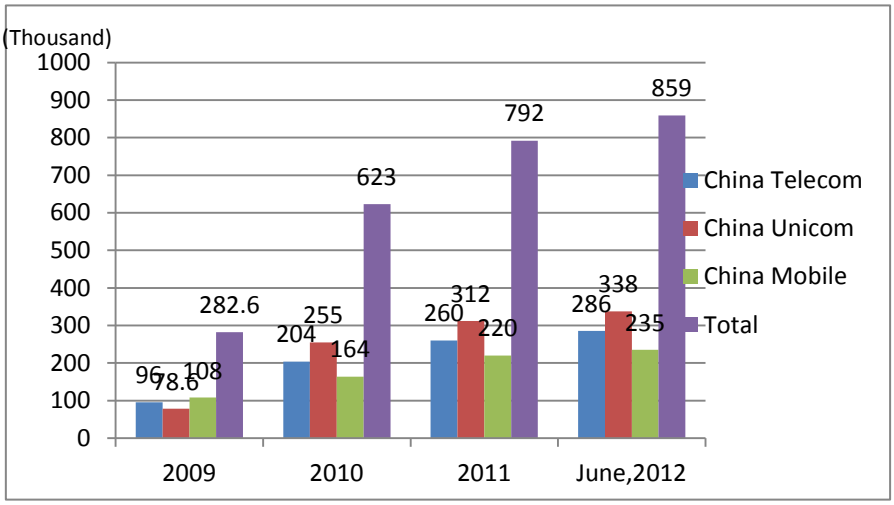


Figure 2-4 3G Base Stations Development in China[4]

Besides, relevant EV-DO Rev.8 tests have been completed by China Telecom in Beijing, Guangzhou, Chengdu, Shanghai, Wuhan and some other big cities. However it is still lack of corresponding terminal models as well as users' requirement on EV-DO Rev.8 currently. A large-scale upgrading has not begun yet but just several trial networks being deployed.

To improve network loading and coverage performance has been regarded as a key objective in China Mobile's workplan. Now some system equipments can already support HSPA+ and more devices and chips are expected to be produced early 2013. China Mobile will take into account service requirement, network evolution strategy and some other factors to decide whether conducting HSPA+ upgrade.

2.4 Terminal

3G terminals shipment is booming nowadays driven by increasingly popularization of 3G service. In the first half of 2012 China shipped over 110 million 3G phones, which occupied over 50% of whole mobile phone shipments. As shown in Figure 2-5, in April, May and June 2012 the proportion of 3G phones reached 57.4% of the total mobile phone shipments.

[4] Source: CATR

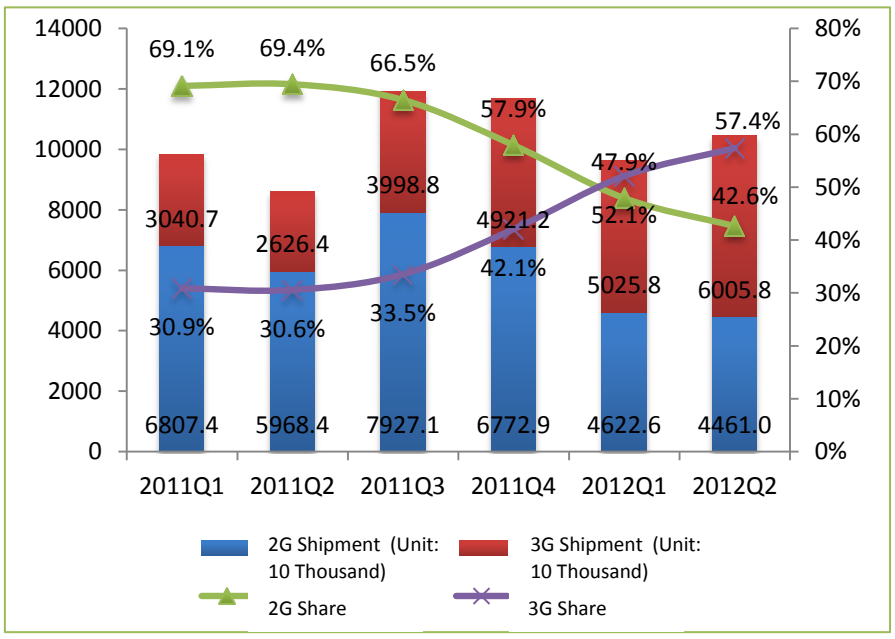


Figure 2-5 2G and 3G Mobile Phone Shipments Comparison[5]

It also should be noticed that smart phones have become the leading character nowadays in China. The mutually promotion of smart phones and mobile internet well stimulates 3G service and further 4G service development. The comparison of smart phone and other phone shipments is illustrated in Figure 2-6. In the second quarter of 2012 China shipped over 55 million Smart phones with proportion of over 50% of total phone shipment, which represents that China has stepped into a "New Smart Era".

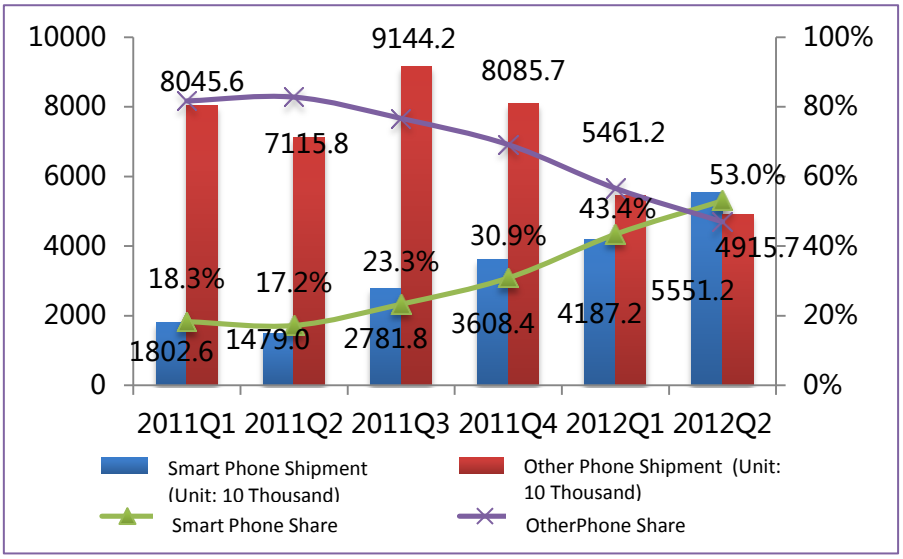


Figure 2-6 Smart Phone /Other Phone Shipments Comparison[6]

[5] Source: CATR

[6] Source: CATR

2.5 Data Service

Mobile internet has become the most popular service among smart phone users. By the end of December 2012 there were 420 million mobile internet users, about 74.5% of the whole internet users in China.

As shown in Figure 2-7 monthly access traffic by mobile internet service reached over 50 million GB in December 2011 which was increased by about 50% in the same period the last year.

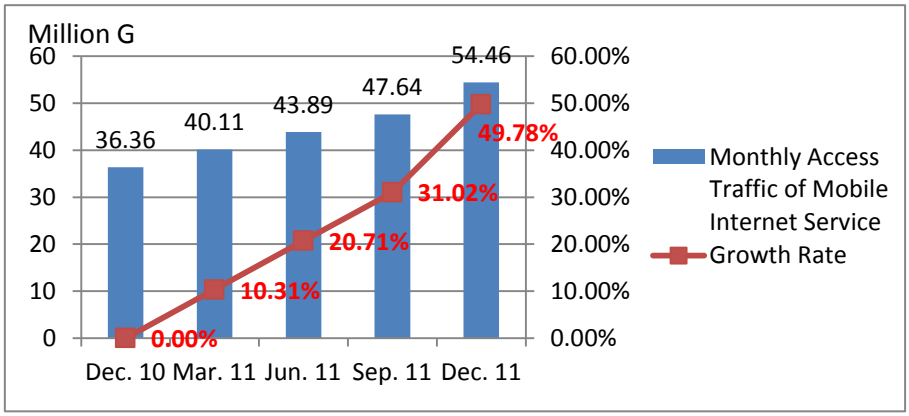


Figure 2-7 Monthly Access Traffic of Mobile Internet from Dec. 2010 to Dec. 2011[7]

The mobile applications' eco-system is gradually perfected. With the proliferation of mobile internet service, Weixin (similar to WhatsApp messenger), Weibo (similar to Twitter), mobile reading, mobile video, etc. are more and more popular among Chinese mobile users while various new applications like mobile payment, wireless city are emerged constantly, which creates huge amount of data traffic. Take Weibo, the most popular "micro blog" internet application in China, for instance in the first half year of 2012 the number of mobile Weibo users rocketed by 33 million reaching 170 million in total (occupying over 60% of all Weibo users) and it was ranked top of the most active mobile internet applications.[8]

The following report will further forecast the future data traffic of mobile service in China by 2020 and nearly 200 Mega-Tera-Byte per year data traffic is estimated in 2020 which is over 600 times of that in 2011.

2.6 TD-LTE Trail

On July 18 2012, Ministry of Industry and Information Technology of P. R. China officially approved the deployment plan of TD-LTE expanded trial in china.

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[7] Source: CATR

[8] Source: CNNIC 30th Internet Development Statistic Report of China

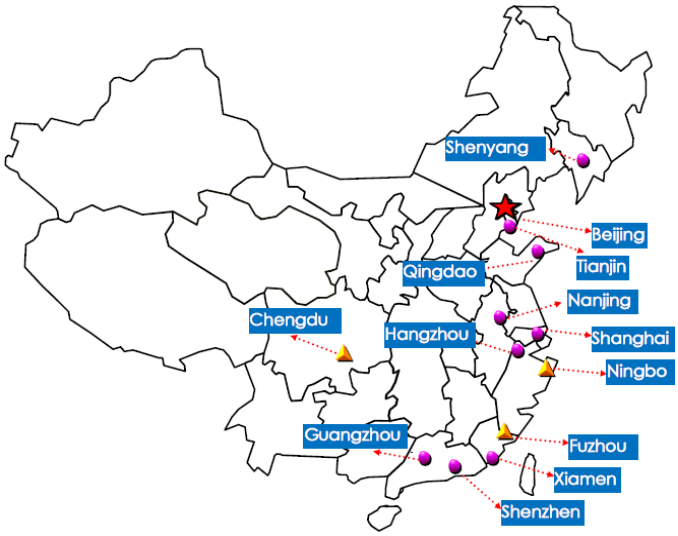


Figure 2-8 TD-LTE Expanded Trial Networks

Before the end of 2012, China Mobile will deploy 20,000 TD-LTE base stations in 13 cities, including Beijing, Tianjin, Shenyang, Shanghai, Nanjing, Hangzhou, Guangzhou, Xiamen, Qingdao, Shenzhen, Fuzhou, Chengdu and Ningbo. 1.9GHz (Band 39) and 2.6GHz (Band 38) will be utilized for outdoor coverage and 2.3GHz (Band 40) for indoor coverage. The number of cities, network scale and frequency bands are much larger compared with the TD-LTE large-scale trial that finished during May 2012. At this phase, the trial will focus on the pre-commercial deployment, network operation and friendly user test.

China is currently trying hard to boost up the commercial deployment of LTE networks.

3. Methodology Overview

3.1 Model Calculation Flow

We have developed a model of spectrum requirements to meet IMT service in China until 2020. Our modelling has considered the spectrum requirements for 2G technologies, 3G technologies and 4G technologies, with the assumption that China commercially launches 4G networks in late 2014.

As shown in Chapter 2, mobile traffic in China would increase dramatically on its network in the future. Operators have two options for increasing their network capacity: acquire more spectrums or deploy more sites. In current context we have provided a reasonable assumption of limited growth in the number of cell sites, considering the history statistics of site increase in recent years in China.

Mobile spectrum demand in each geographic type is estimated respectively in our model: urban, suburban and rural areas. The model therefore includes appropriate geotype-segmented input and analysis to support network assumptions.

The calculation flows with their key inputs and calculations are illustrated in Figure 3-1. All the inputs are explained in detail in Section 4.

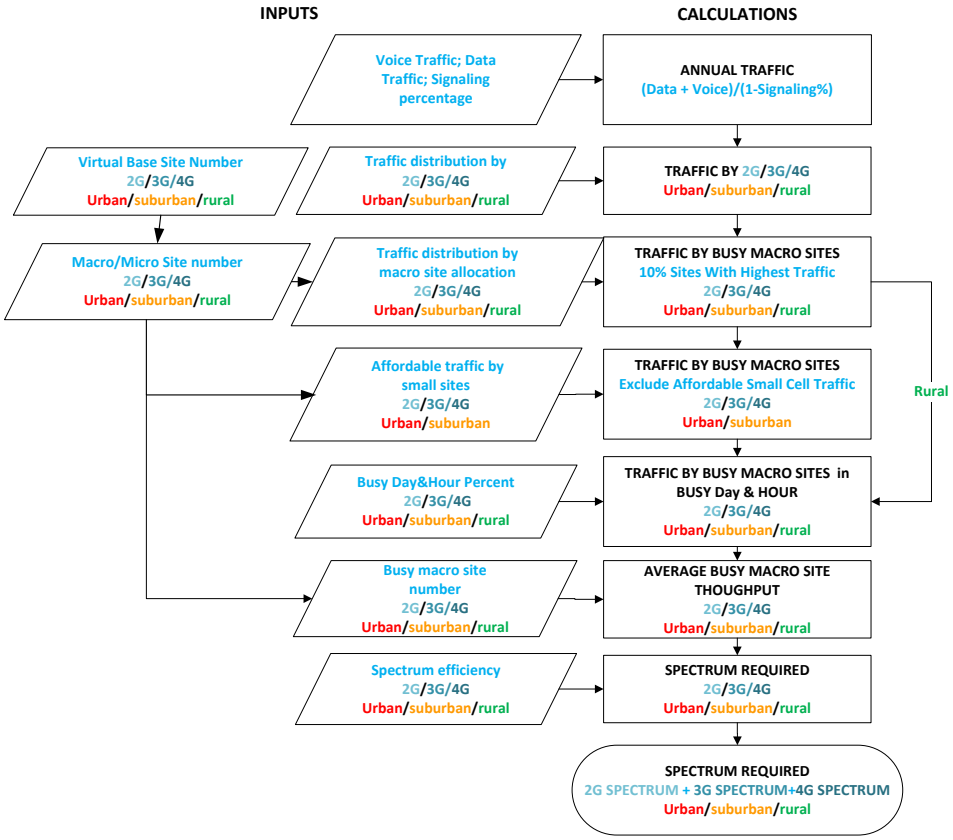


Figure 3-1 CATR Model Calculation Flow

3.2 Key Assumptions

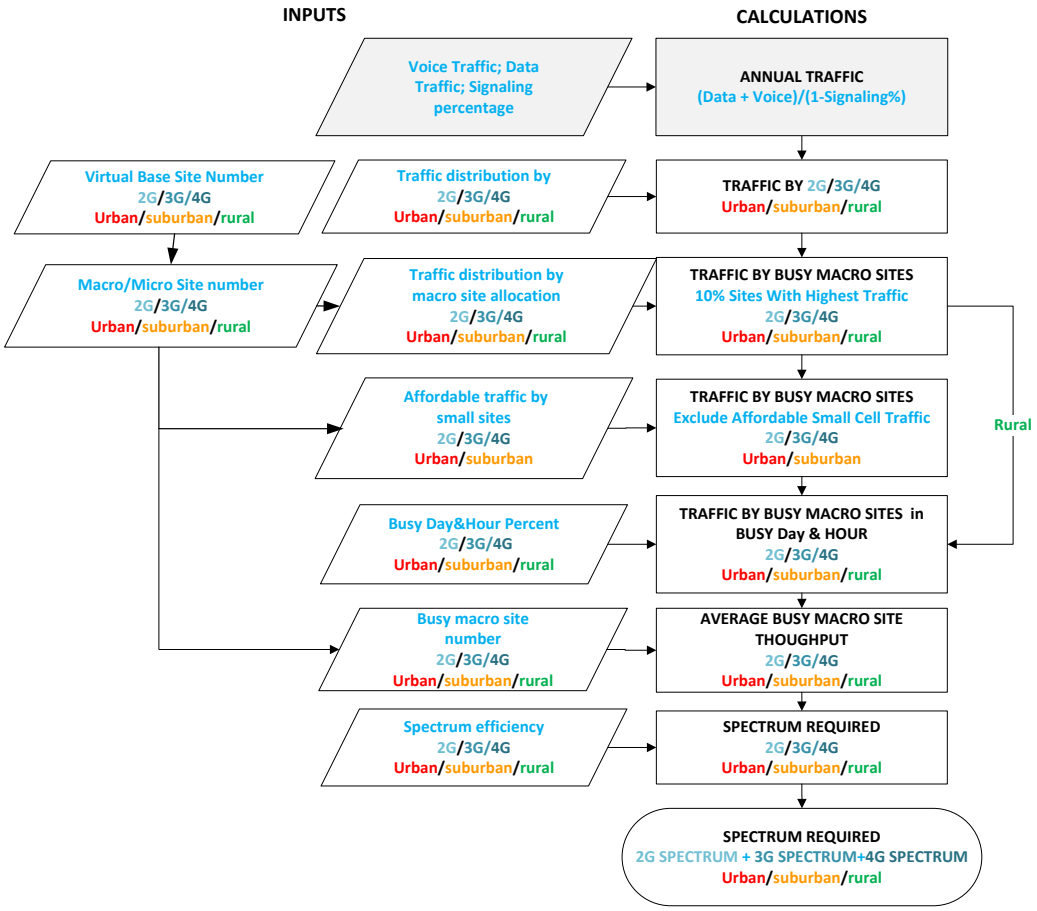
There are several fundamental assumptions to support our model:

- ✧ The traffic and spectrum requirement of IMT service are estimated while WLAN traffic is excluded.
- ✧ Segmentation by geographic type: urban, suburban, rural and it is assumed that the traffic proportions of the 3 geotypes keeps the same until 2020: 60%, 28% and 12% according to experts consulting and literature review;
- ✧ Number of operators are assumed to keep three until 2020;
- ✧ The launching time of 4G service in China is assumed to be late 2014;
- ✧ The expanding of 2G base stations deployment is assumed to be stopped after 2014 and the number would keep stable;
- ✧ Higher layer signalling percentage of the whole traffic is assumed to be 10%;
- ✧ Traffic of 20% of 365 Days occupies 40% of whole year traffic (20% Busy Days) and Busy Hour traffic occupies 10% of a whole Busy Day traffic;
- ✧ The maximum load rate of macro cell is 85%, and that of small cell is 75%;
- ✧ The downlink traffic occupies 80% of the total traffic;
- ✧ The basic LTE spectrum for each operator is assumed to be 20 MHz.

4. Model Input

4.1 Annual Traffic

In this section, the calculation steps marked by grey color as below are explained.



The annual traffic is based on the following calculation:

$$\text{Annual traffic} = \frac{(\text{Annual Voice Traffic}+\text{Annual Data Traffic})}{(1-\text{Signalling\%})} \quad (4\text{-}1)$$

4.1.1 Voice Traffic Estimation

Table 4-1 shows the statistics of Annual Voice Minutes from each operator's annual report in recent 4 years.

Table 4-1 Annual Voice Minutes of 3 operators

China Mobile				
	2008	**2009**	**2010**	**2011**
Voice Minutes (Billion Minutes)	2441.3	2918.7	3461.6	3887.2

Subscriptions(Million)	457	522	584	650
Voice Minutes per User(Minutes/year)	5342.01	5591.38	5927.40	5980.31
Voice Minutes per User Growth Rate		4.67%	6.01%	0.89%
Voice Minutes Growth Rate		19.56%	18.60%	12.29%
Subscriptions Growth Rate		14.22%	11.88%	11.30%
China Unicom				
	2008	**2009**	**2010**	**2011**
Voice Minutes (Billion Minutes)	376.67	423.05	526.47	654.26
Subscriptions(Million)	133	145	167	199
Voice Minutes per User(Minutes/year)	2832.11	2917.59	3152.51	3287.74
Voice Minutes per User Growth Rate		3.02%	8.05%	4.29%
Voice Minutes Growth Rate		12.31%	24.45%	24.27%
Subscriptions Growth Rate		9.02%	15.17%	19.16%
China Telecom				
	2008	**2009**	**2010**	**2011**
Voice Minutes (Billion Minutes)	26.375	155.41	295.885	392.67
Subscriptions(Million)	28	56	91	126
Voice Minutes per User(Minutes/year)	941.96	2775.18	3251.48	3116.43
Voice Minutes per User Growth Rate		194.62%	17.16%	-4.15%
Voice Minutes Growth Rate		489.23%	90.39%	32.71%
Subscriptions Growth Rate		100.00%	62.50%	38.46%

It should be noted that the voice minute statistics are recorded from BOSS（Business & Operation Support System）which takes the call duration in the last minute of less than 1 minute as 1 minute. Therefore the recorded voice minutes are higher than the actual duration which should be used in the traffic estimation. In order to estimate the actual voice traffic in the network, we take the following actions:

a) Assign the whole voice minutes into different categories in terms of actual call durations.

All the voice minutes were produced from different durations of calls. In our model 21 duration groups are considered. And in each group the voice minutes proportion of the whole minutes are estimated in Table 4-2, according to which the voice minutes of each group can be calculated.

Table 4-2 Voice Minute Assignment

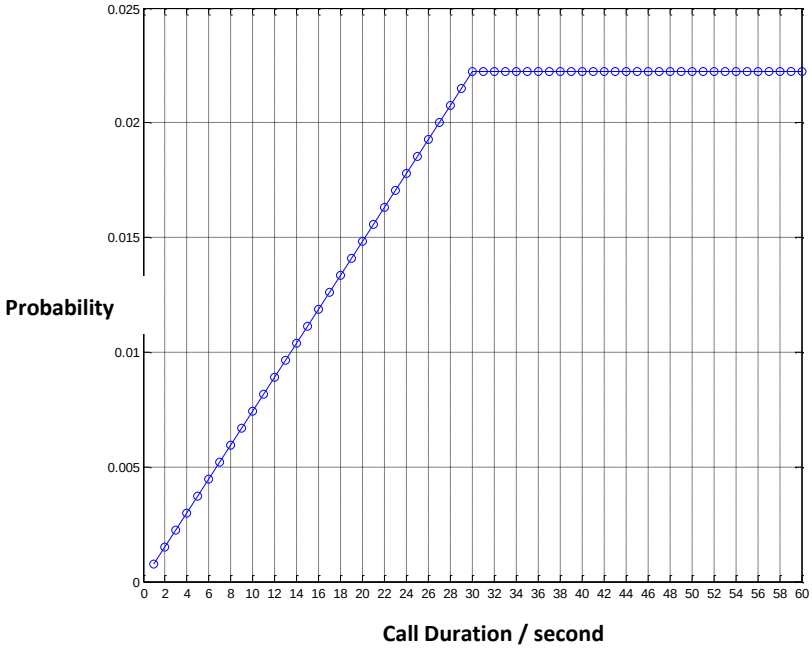
Duration Groups	Proportion	Accumulative

		proportion
1 minute and less	40.00%	40.00%
1 to 2 minutes	30.00%	70.00%
2 to 3 minutes	14.00%	84.00%
3 to 4 minutes	7.00%	91.00%
4 to 5 minutes	4.00%	95.00%
5 to 6 minutes	2.00%	97.00%
6 to 7 minutes	0.85%	97.85%
7 to 8 minutes	0.43%	98.28%
8 to 9 minutes	0.31%	98.59%
9 to 10 minutes	0.12%	98.71%
10 to 11 minutes	0.12%	98.83%
11 to 12 minutes	0.12%	98.95%
12 to 13 minutes	0.12%	99.07%
13 to 14 minutes	0.12%	99.19%
14 to 15 minutes	0.12%	99.31%
15 to 16 minutes	0.12%	99.43%
16 to 17 minutes	0.12%	99.55%
17 to 18 minutes	0.12%	99.67%
18 to 19 minutes	0.12%	99.79%
19 to 20 minutes	0.12%	99.91%
20 minutes and longer （Uniform probability distribution is assumed between 20 and 100 minutes）	0.09%	100.00%

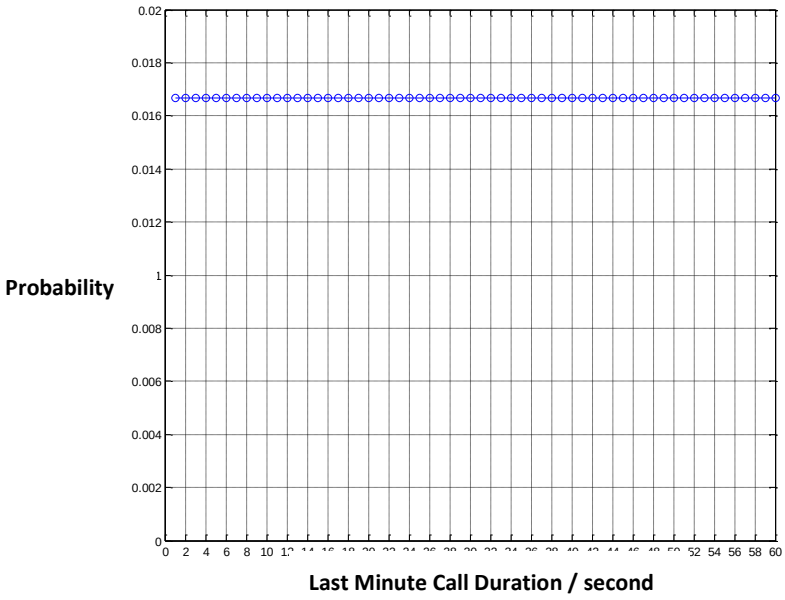
b) Utilise probability distribution of "termination time of each call" to estimate actual voice minutes for each group.

In each group, each call ends at 1 to 60 seconds of the last minute randomly. Through utilising probability distribution model for each group the actual voice minute can be estimated. In our model:

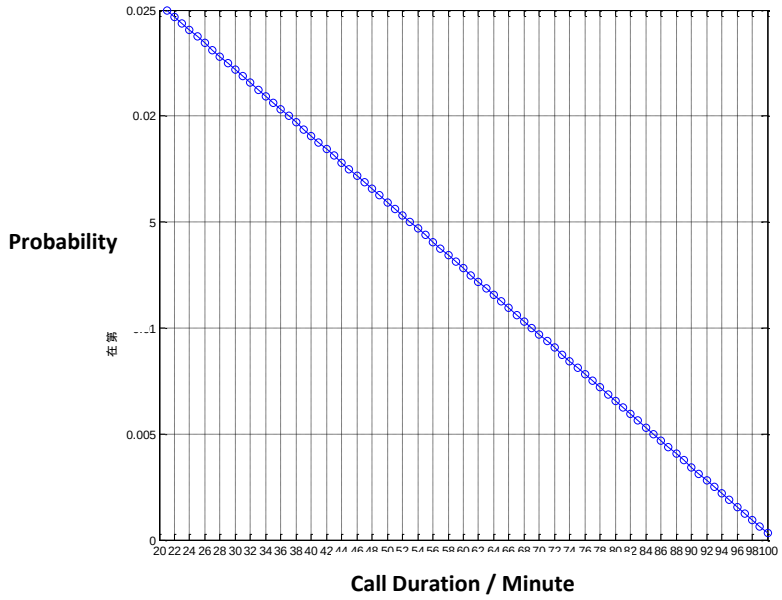
- Group 1 (Call with 1 minute and less): The termination time of each call is assumed to obey the following probability distribution.



— Group 2 to Group 20 (1~20 minutes call）: The termination time of each call in the last minute is assumed to obey uniform distribution between 1 to 60 seconds as shown below.



— Group 21 (Call duration with 20 minutes and longer)： It is assumed that all calls end in 100 minutes(a longer than 100 minutes call would be of quite little probability) And call duration between 20 and 100 minutes obeys linear distribution as shown below. The termination time of each call in the last minute is assumed to obey uniform distribution.



The adjusted voice minutes thus can be translated from the BOSS system records and estimations as Table 4-4 shown. The detailed adjusting calculation algorithm with MATLAB program is given in Annex 2.

Then the voice minutes are transformed into voice traffic in kbps with AMR voice coding. The data rate modes of AMR are shown in Table 4-3. By giving utilisation rate, we can get the average data rate.

Table 4-3 Average AMR Data Rate Estimation

AMR Data Rate Mode/kbps	Utilisation Proportion
4.75	1%
5.15	2%
5.9	4%
6.7	4%
7.4	5%
7.95	12%
10.2	24%
12.2	48%
Average data rate	10.2825 kbps

Therefore the equivalent voice traffic can be calculated based on the above estimations. Table 4-4 shows the voice traffic calculated and estimated from 2008 to 2020 in China. Since there is very limited growing space of voice minutes per user, the growth rate of voice minutes, thus that of voice traffic, keeps going down.

Table 4-4 Voice Minutes Adjustment

Year	Voice Minutes (Billion Minutes/year)	Yearly growth Rate	Adjusted Voice Minutes (Billion Minutes/Year)	Voice Traffic (ktb/year)
2008	2844.35		2095.03	1292.213
2009	3497.16	23%	2576.19	1588.996
2010	4283.96	22%	3155.79	1946.491
2011	4934.13	15 %	3634.74	2241.909
2012	5575.57	13 %	4107.26	2533.357
2013	6188.88	11 %	4559.06	2812.027
2014	6745.88	9 %	4969.37	3065.109
2015	7150.63	6 %	5267.54	3249.016
2016	7436.66	4 %	5478.24	3378.976
2017	7734.12	4 %	5697.37	3514.136
2018	8043.49	4 %	5925.26	3654.701
2019	8365.23	4 %	6162.27	3800.889
2020	8699.84	4 %	6408.76	3952.924

4.1.2 Data Traffic Estimation

Data traffic estimation is based on the following flow.

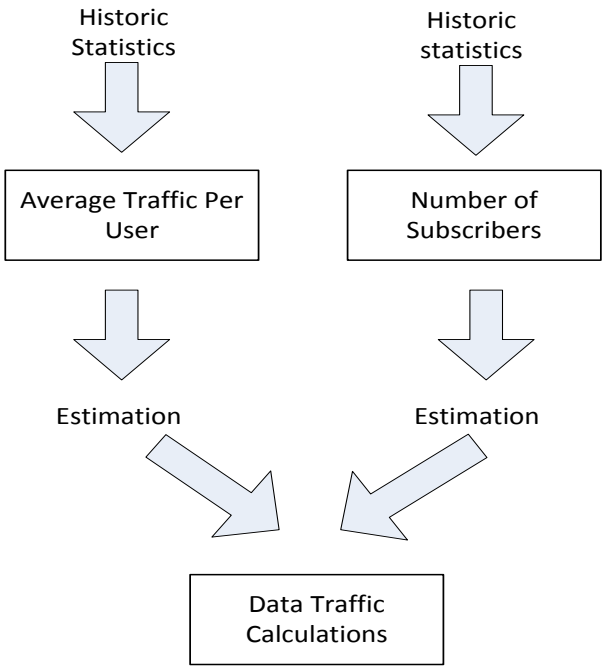


Figure 4-1 Data Traffic Estimation Flow

a) Data traffic per user prediction

The annual data traffic in China is estimated by data traffic per subscriber per year and subscriber number. The average traffic per user per year from 2010 to 2011 can

be calculated from the 3 operators' Annual Reports, which could be found in Table 4-5.

Note: Only the traffic for IMT is analysed, and the traffic of WLAN is precluded.

Table 4-5 Traffic per user per year Statistics during 2010 to 2011

Year	Weighted Average(MB/user/year)	Increase
2010	166.83	N.A.
2011	325.26	**94.96%**

Assuming a growth rate of 95% from 2012 to 2020, the data traffic per user per year is estimated shown in Table 4-6.

Table 4-6 Data Traffic per User per year Estimation

Year	Average Annual Traffic per user (MB)	Growth Rate
2010	166.83	N.A.
2011	325.26	94.96%
2012	634.257	95%
2013	1236.80115	95%
2014	2411.762243	95%
2015	4702.936373	95%
2016	9170.725927	95%
2017	17882.91556	95%
2018	34871.68534	95%
2019	67999.78641	95%
2020	132599.5835	95%

b) Subscribers prediction

The number of subscribers is estimated based on S-Curve method by:

- History statistic of population, mobile subscriber penetration rate;
- Utilising least-square linear regression fitting method to forecast population growth;
- Utilising S-curve method to evaluate the future penetration rate：

$$y(x) = \frac{1}{A+B*\exp(-C*x)} \quad (4\text{-}3);$$

Specifically, A represents the largest penetration rate estimated from expert inquiries as shown in Table 4-7 while B and C are estimated by history statistics.

Table 4-7 Largest Penetration Rate Estimation

Companies/Organisation	Largest penetration rate
CATR	120
China Unicom	120
China Telecom	125
China Mobile	105
CATT	104
Average	**110**

— Finally number of subscriptions can be calculated with population and penetration rate estimations. (see Table 4-8 and Figure 4-2)

Table 4-8 2000-2020 China Mobile Subscription Estimations

Year	Population (Thousand)	Penetration rate (%)	Subscriptions (Thousand)
2000	1267430	6.72699873	85260
2001	1276270	11.34712874	144820
2002	1284530	16.03738332	206005
2003	1292270	20.88982952	269953
2004	1299880	25.75806998	334824
2005	1307560	30.08703234	393406
2006	1314480	35.07531495	461058
2007	1321290	41.42209507	547306
2008	1328020	48.28579389	641245
2009	1334740	55.981989	747214
2010	1339725	64.11763608	859000
2011	1349570.364	72.452	977790.7199
2012	1356829.136	78.8958	1070481.202
2013	1364087.909	84.6211	1154306.194
2014	1371346.682	89.5655	1228253.512
2015	1378605.455	93.7319	1292193.086
2016	1385864.227	97.1704	1346649.813
2017	1393123	99.96	1392565.751
2018	1400381.773	102.1918	1431075.34
2019	1407640.545	103.9574	1463346.512
2020	1414899.318	105.342	1490483.24

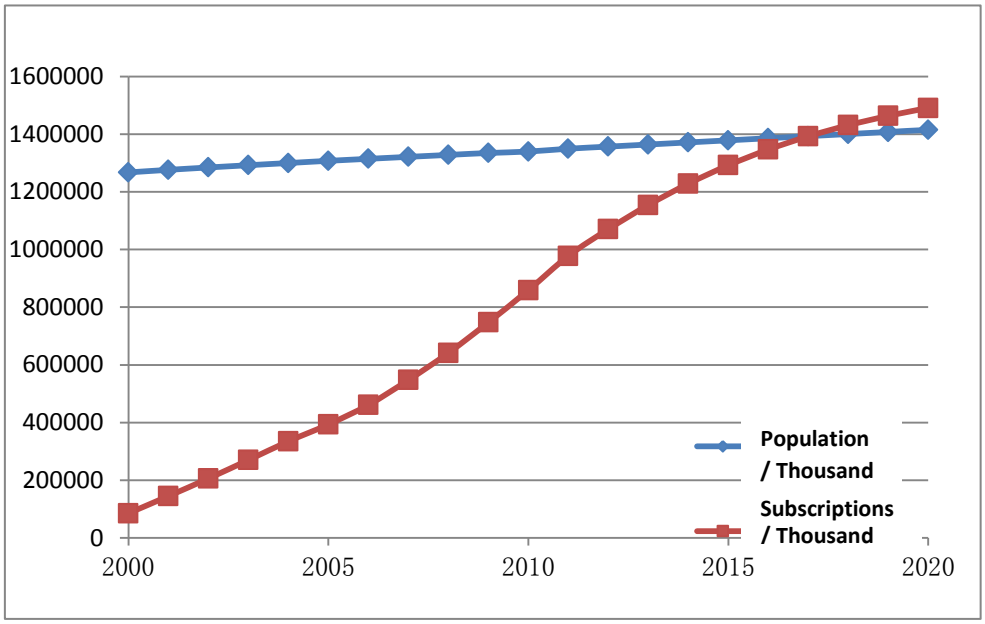


Figure 4-2 Growths of Population and Mobile Subscriptions from 2000 to 2020

a) Annual data traffic prediction

According to Table 4-6 and Table 4-8 the annual data traffics are calculated as Table 4-9 shown below.

Table 4-9 Annual Data Traffic

Year	Annual Data Traffic (kTB)	Growth Rate	Growth Raletive to 2011
2010	143.31	N.A.	
2011	318.04	121.92%	
2012	678.96	113.49%	2.13
2013	1427.65	110.27%	4.49
2014	2962.26	107.49%	9.31
2015	6077.10	105.15%	19.11
2016	12349.76	103.22%	38.83
2017	24903.14	101.65%	78.30
2018	49904.01	100.39%	156.91
2019	99507.25	99.40%	312.88
2020	197637.46	98.62%	621.43

4.1.3 Total Traffic Estimation

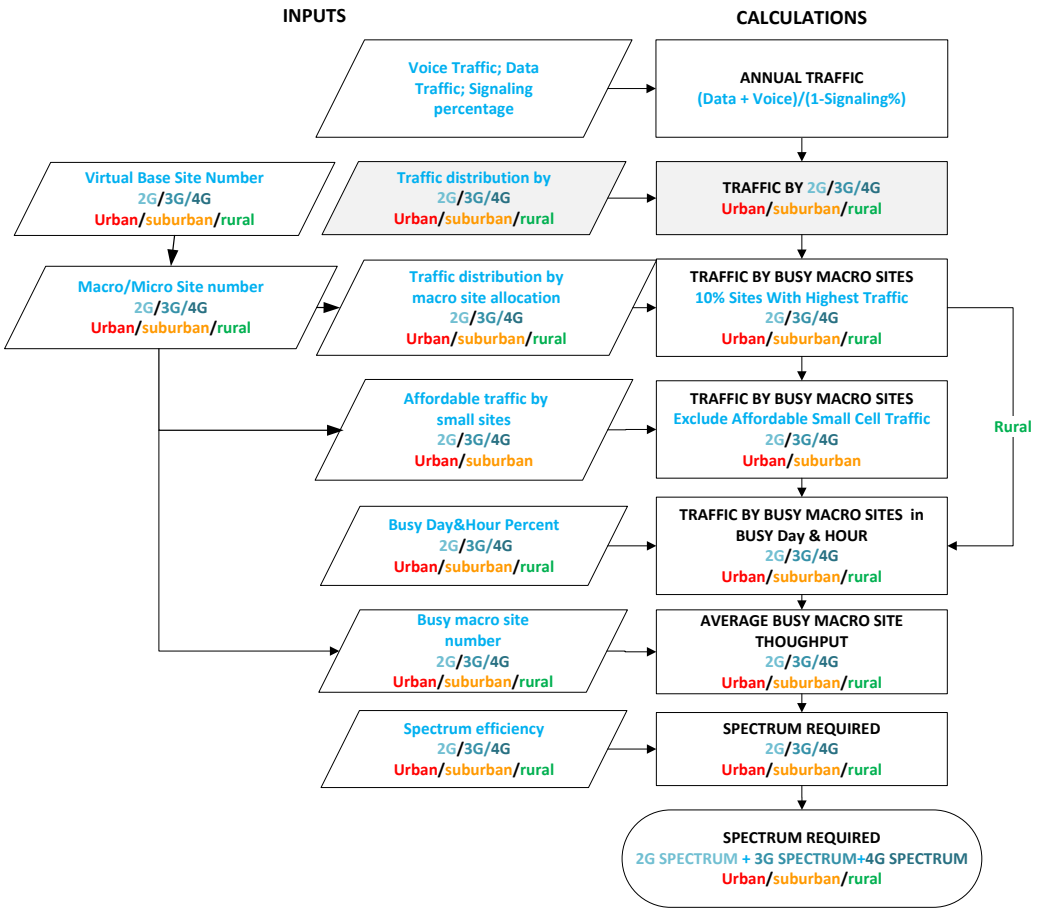
The total annual traffic can be calculated with Table 4-4, Table 4-9 and equation 4-1:

Table 4-10 Total Annual Mobile Traffic Estimation

	Annual Data Traffic /KTB	Annual Voice Traffic /kTB	Annual Traffic /kTB	Data Traffic Proportion	1-Signalling%	**Total Traffic/kTB (including signalling overhead)**
2010	143.31	1946.491	2089.80	6.86%	90%	**2786.403**
2011	318.04	2241.909	2559.95	12.42%	90%	**3413.261**
2012	678.96	2533.357	3212.32	21.14%	90%	**4283.09**
2013	1427.65	2812.027	4239.67	33.67%	90%	**5652.898**
2014	2962.26	3065.109	6027.36	49.15%	90%	**8036.486**
2015	6077.10	3249.016	9326.12	65.16%	90%	**12434.82**
2016	12349.76	3378.976	15728.73	78.52%	90%	**20971.64**
2017	24903.14	3514.136	28417.27	87.63%	90%	**37889.69**
2018	49904.01	3654.701	53558.71	93.18%	90%	**71411.61**
2019	99507.25	3800.889	103308.14	96.32%	90%	**137744.2**
2020	197637.46	3952.924	201590.38	98.04%	90%	**268787.2**

4.2 Traffic Distribution by technologies and genotypes

In this section, the calculation steps marked by grey color as below are explained.



4.2.1 Traffic Distribution by Technologies

To obtain the 2G/3G/4G traffic distribution in China, the calculation procedure shown in Figure 4-3 is used.

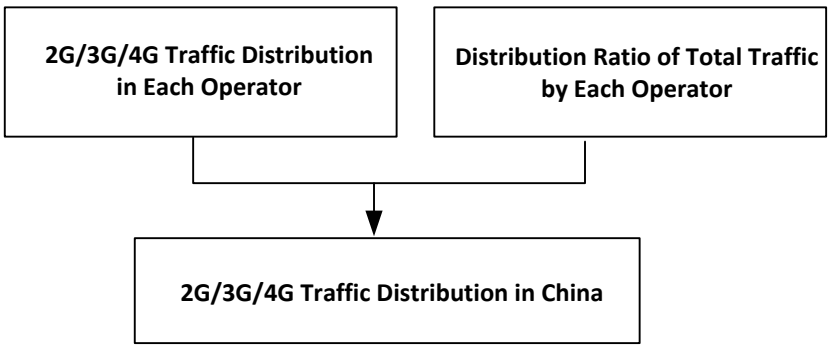


Figure 4-3 Traffic Distribution Calculation Procedure

In China, 3G was launched in 2009. According to China Unicom's annual report, it can be found that the traffic distribution between 2G and 3G in Year 2010 and Year 2011, as shown in Figure 4-4.

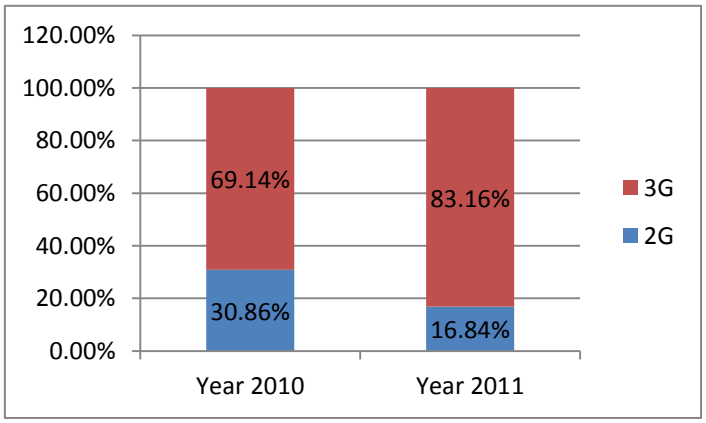


Figure 4-4 China Unicom's traffic distribution between 2G and 3G

Referring to Figure 4-4, we give the assumption of traffic distribution between 2G and 3G for China Mobile and China Telecom. As China Unicom's WCDMA is a very mature technology and has perfect industrial chain, its traffic distribution for 3G is estimated to be larger than China Mobile's TD-SCDMA and China Telecom's CDMA2000.

Table 4-11 shows the distribution ratio of total traffic by the 3 operators in accordance with their annual reports.

Table 4-11 Traffic Ratio in 2010 and 2011

Year	2010	2011
China Unicom	17.28%	30.15%

China Telecom	9.41%	19.09%
China Mobile	73.31%	50.77%
sum	100%	100%

According to above analysis, the 2G and 3G traffic distribution rate in China is calculated during 2010 and 2011, as shown in Table 4-12. And 2G, 3G and 4G traffic distribution rates in future years are also estimated. It should be noted that 2G traffic is assumed to be unchanged after 2015 (Because the total traffic keeps rapid growth after 2015, 2G traffic distribution rate keeps going down).

Table 4-12 Estimated Traffic distributions by 2G, 3G and 4G services

	2G	3G	4G
2010	74.81%	25.19%	
2011	49.51%	50.49%	
2012	37.00%	63.00%	
2013	28.00%	71.00%	
2014	21.00%	77.00%	
2015	14.86%	78.14%	7.00%
2016	8.81%	66%	25.19%
2017	4.88%	44.63%	50.49%
2018	2.59%	34.41%	63%
2019	1.34%	27.66%	71%
2020	0.69%	22.31%	77%

4.2.2 Traffic Distribution by Geotypes

The traffic distribution among different environments is assumed in Table 4-13.

Table 4-13 Traffic distribution by 3 geotypes

Geotype	urban	suburban	rural
Traffic distribution	60%	28%	12%

In general new technologies are firstly deployed in urban area so that the traffic distribution rate of urban area during early deployment stage is larger than the assumption in Table 4-13. The detailed traffic distributions of 2G, 3G and 4G are shown in Table 4-14, Table 4-15 and Table 4-16, respectively.

Table 4-14 2G Traffic distribution by 3 geotypes during 2010 to 2020

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
urban	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%
suburban	28%	28%	28%	28%	28%	28%	28%	28%	28%	28%	28%
rural	12%	12%	12%	12%	12%	12%	12%	12%	12%	12%	12%

Table 4-15 3G Traffic distribution by 3 geotypes during 2010 to 2020

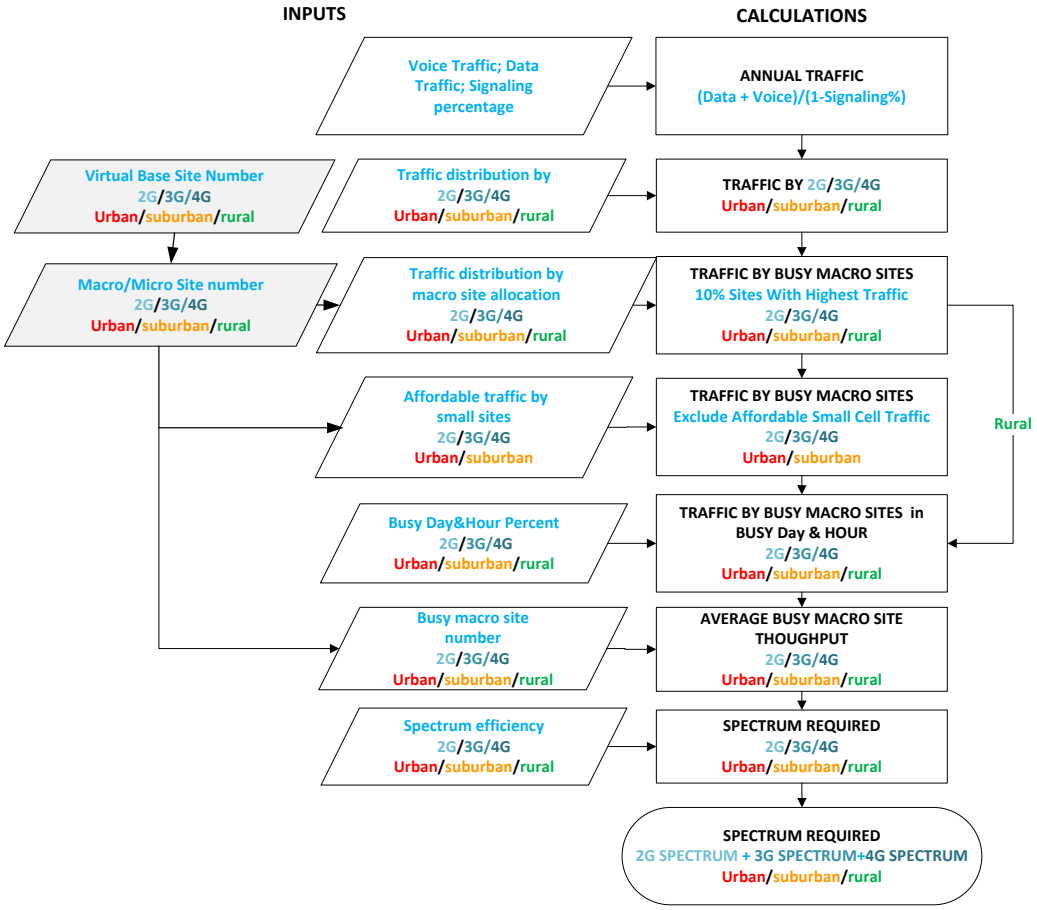
场景	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
urban	70%	64%	60%	60%	60%	60%	60%	60%	60%	60%	60%
suburban	25%	28%	28%	28%	28%	28%	28%	28%	28%	28%	28%
rural	5%	8%	12%	12%	12%	12%	12%	12%	12%	12%	12%

Table 4-16 4G Traffic distribution by 3 geotypes during 2010 to 2020

		2015	2016	2017	2018	2019	2020
urban		79%	70%	64%	60%	60%	60%
suburban		20%	25%	28%	28%	28%	28%
rural		1%	5%	8%	12%	12%	12%

4.3 Site Number Estimation

In this section, the calculation steps marked by grey color as below are explained.



4.3.1 Total Base Station Estimation

According to the statistics of base stations from 2009 to 2011 as shown in Table 4-17, the average yearly growth rate of base stations was as high as **37.44%** in China, especially the 67.32% growth rate of 2009 in which year 3G licenses were issued and large-scale construction of 3G BSs began.

Table 4-17 The Number of Base Stations in China

			Total Base Staion Number in China										
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
2G BS	688500	875000	1089000	1375000	1650000	1848000	1921920	1921920	2E+06	1921920	1921920	1921920	1921920
3G BS		277000	461000	728500	1019900	1223880	1407462	1548208	2E+06	1706900	1758107	1793269	1829134
4G BS								250000	412500	639375	895125	1074150	1235273
Total BS Number	688500	1152000	1550000	2103500	2669900	3071880	3329382	3720128	4E+06	4268195	4575152	4789339	4986327
2G growth rate		27.09%	24.46%	26.26%	20%	12%	4%	0%	0%	0%	0%	0%	0%
3G growth rate			66.43%	58.03%	40%	20%	15%	10%	5%	5%	3%	2%	2%
4G growth rate									65%	55%	40%	20%	15%
Average growth rate		67.32%	34.55%	35.71%	26.93%	15.06%	8.38%	11.74%	6.45%	7.78%	7.19%	4.68%	4.11%

According to the number of base stations from 2009 to 2011, the number of base stations in future years are estimated in Table 4-17 above. As for 2G BS trend, it is expected that the expanding of 2G BSs deployment will be slower in the next 5 years and even stop after 2015. Besides, China is expected to issue 4G licenses in late 2014, which would lead to large construction of 4G BS in 2015, 2016 and 2017. Referring to the early status of 3G deployments, the growth rate of 4G BSs would be around 65% in 2016 and gradually lower to 15%.

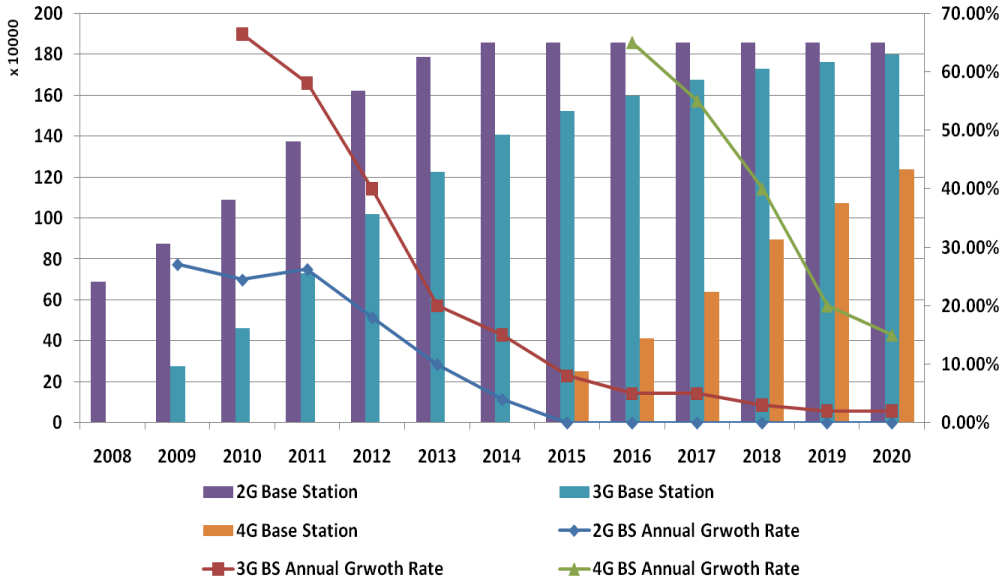


Figure 4-5 The Number of Base Stations in China

4.3.2 Total Virtual Base Site Estimation

For china has 3 operators, we assume that each operator has similar coverage. Thus, the number of virtual base site is assumed to be one third of the number of base stations. Table 4-19 illustrates the estimation of number of base sites of 2G/3G/4G respectively. (About “virtual base site” please refer to Annex 1)

Table 4-18 Number of Virtual Base Sites in China

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
2G Base Sites	229500	291667	363000	458333	540833	594917	618713	618713	618713	618713	618713	618713	618713
3G Base Sites		92333	153667	242833	339967	407960	469154	516069	541873	568967	586036	597756	609711
4G Base Sites								83333	137500	213125	298375	358050	411758

4.3.3 Macro/Small Base Sites Estimation

By assuming the distribution rate of macro base sites in additional base sites of each year, the addition of macro base sites and small base sites in each year could be calculated. Thus, the number of macro base sites and small base sites are obtained. The detailed number is shown in Table 4-19. Note: at the early stage of network deployment, the operator mainly focuses on macro base sites constructions, after which the proportion of small BSs would be gradually increased.

Table 4-19 Macro/Small Base Sites Distribution Estimation of 2G/3G/4G

2G Macro/Small Base Sites													
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
2G Macro BSs Distribution Rate	80.00%	71.47%	65.29%	56.91%	52.04%	48.22%	46.75%	46.75%	46.75%	46.75%	46.75%	46.75%	46.75%
Addition of 2G BSs		62167	71333	95333	82500	54083	23797	0	0	0	0	0	0
Distribution Rate of Macro BSs in addition BSs		40.00%	40.00%	25.00%	25.00%	10.00%	10.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Addition of Macro BSs		24867	28533	23833	20625	5408	2380	0	0	0	0	0	0
Addition of Small BSs		37300	42800	71500	61875	48675	21417	0	0	0	0	0	0
Number of Macro BSs	183600	208467	237000	260833	281458	286867	289246	289246	289246	289246	289246	289246	289246
Number of Small BSs	45900	83200	126000	197500	259375	308050	329467	329467	329467	329467	329467	329467	329467

3G Macro/Small Base Sites													
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
3G Macro BSs Distribution Rate		90.00%	82.02%	73.93%	67.09%	62.58%	59.63%	56.03%	54.32%	52.20%	50.83%	49.93%	49.05%
Addition of 3G BSs			61333	89167	97133	67993	61194	46915	25803	27094	17069	11721	11955
Distribution Rate of Macro BSs in addition BSs			70.00%	60.00%	50.00%	40.00%	40.00%	20.00%	20.00%	10.00%	5.00%	5.00%	5.00%
Addition of Macro BSs			42933	53500	48567	27197	24478	9383	5161	2709	853	586	598
Addition of Small BSs			18400	35667	48567	40796	36716	37532	20643	24384	16216	11135	11357
Number of Macro BSs		83100	126033	179533	228100	255297	279775	289158	294319	297028	297882	298468	299065
Number of Small BSs		9233	27633	63300	111867	152663	189379	226911	247554	271938	288154	299289	310646

4G Macro/Small Base Sites													
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
3G Macro BSs Distribution Rate								100.00%	92.12%	84.27%	77.34%	72.78%	68.51%
Addition of 3G BSs								83333	54167	75625	85250	59675	53708
Distribution Rate of Macro BSs in addition BSs									80.00%	70.00%	60.00%	50.00%	40.00%
Addition of Macro BSs									43333	52938	51150	29838	21483
Addition of Small BSs									10833	22688	34100	29838	32225
Number of Macro BSs								83333	126667	179604	230754	260592	282075
Number of Small BSs								0	10833	33521	67621	97458	129683

4.3.4 Macro Base Site Distribution by 3 Geotypes

According to “2007 China Land Area Report”, the areas of different land types are listed in Table 4-20.

Table 4-20 Areas of Different Land Types of China

Land Type	Area(kilo km^2)	Percentage
Arable land	1217.352	12.81%
Garden	118.131	1.24%
Woodland	2361.174	24.84%
Crazing Land	2618.646	27.55%
Other Farmland	254.911	2.68%
Residential Area	266.472	2.80%
Transportation Area	24.443	0.26%
Facilities Area	36.286	0.38%
Unused Land	2608.611	27.44%
Total	9506.026	100.00%

In Fact not all land types are covered by mobile services so that we estimate a coverage rate for each land type thus working out the coverage areas. Moreover, land area distributions in urban, suburban and rural type is estimated to give the coverage areas of urban, suburban and rural respectively as shown in Table 4-21.

Table 4-21 Mobile Coverage Rates and Areas and land distribution in the three geotypes

Land Type	Coverage Rate	Coverage Area (kilo km^2)	Urban	Urban Coverage Area	Suburban	Suburban Coverage Area	Rural	Rural Coverage Area
Arable land	85%	1034.75	0%	0.00	7%	72.43	93%	962.32
Garden	85%	100.41	0%	0.00	2%	2.01	98%	98.40
Woodland	50%	1180.59	0%	0.00	2%	23.61	98%	1156.98
Crazing Land	55%	1440.26	0%	0.00	2%	28.81	98%	1411.45
Other Farmland	85%	216.67	0%	0.00	2.50%	5.42	97.50%	211.26
Residential Area	95%	253.15	13%	32.91	37%	93.66	50%	126.57
Transportation Area	95%	23.22	5%	1.16	30%	6.97	65%	15.09
Facilities Area	85%	30.84	0%	0.00	20%	6.17	80%	24.67
Unused Land	40%	1043.44	0%	0.00	0%	0.00	100%	1043.44
Total Coverage Area		5323.33		34.07		239.07		5050.19
Total Coverage Rate		56.00%						

The average site spacing is assumed as Table 4-22 listed. The number of macro base sites for the three area types can be approximated by the total coverage area and average cell area in each type. Thus the Macro base site distribution rates by the 3 geotypes can be obtained which are 22.85%, 24.24% and 52.91% respectively.

Table 4-22 Sites Distribution Estimation by urban, suburban and rural areas

Geotype	Average Site Spacing(km)	Average Cell Area(km^2)	Site Number (Thousand)	Percentage
urban	0.7	0.4263	79.92	22.85%
suburban	1.8	2.8188	84.81	24.24%
rural	5.6	27.2832	185.10	52.91%
			349.84	

It should be noticed that the distribution here should be the final status while most sites are expected to be built in urban area in the early stage of network deployment. Therefore, we assume that the distribution rate of urban is higher in the first several years of new network deployment, which is shown in Table 4-23.

Table 4-23 Macro Sites Distribution Estimation by 3 Geotypes

2G Macro BSs Distribution Rate among 3 Geotypes													
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
urban	23%	23%	23%	23%	23%	23%	23%	23%	23%	23%	23%	23%	23%
suburban	24%	24%	24%	24%	24%	24%	24%	24%	24%	24%	24%	24%	24%
rural	53%	53%	53%	53%	53%	53%	53%	53%	53%	53%	53%	53%	53%
	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

3G Macro BSs Distribution Rate among 3 Geotypes													
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
urban		65%	46%	34%	27%	25%	23%	23%	23%	23%	23%	23%	23%
suburban		30%	37%	35%	29%	26%	24%	24%	24%	24%	24%	24%	24%
rural		5%	17%	31%	44%	49%	53%	53%	53%	53%	53%	53%	53%
		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

4G Macro BSs Distribution Rate among 3 Geotypes													
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
urban								65%	46%	34%	27%	25%	23%
suburban								30%	37%	35%	29%	26%	24%
rural								5%	17%	31%	44%	49%	53%
								100%	100%	100%	100%	100%	100%

4.3.5 Small Base Site Distribution by 3 Geotypes

In terms of small cell, the majority would be deployed in urban area especially the early stage of network deployments. Detailed information is shown in Table 4-24.

Table 4-24 Small Sites Distribution Estimation by 3 Geotypes

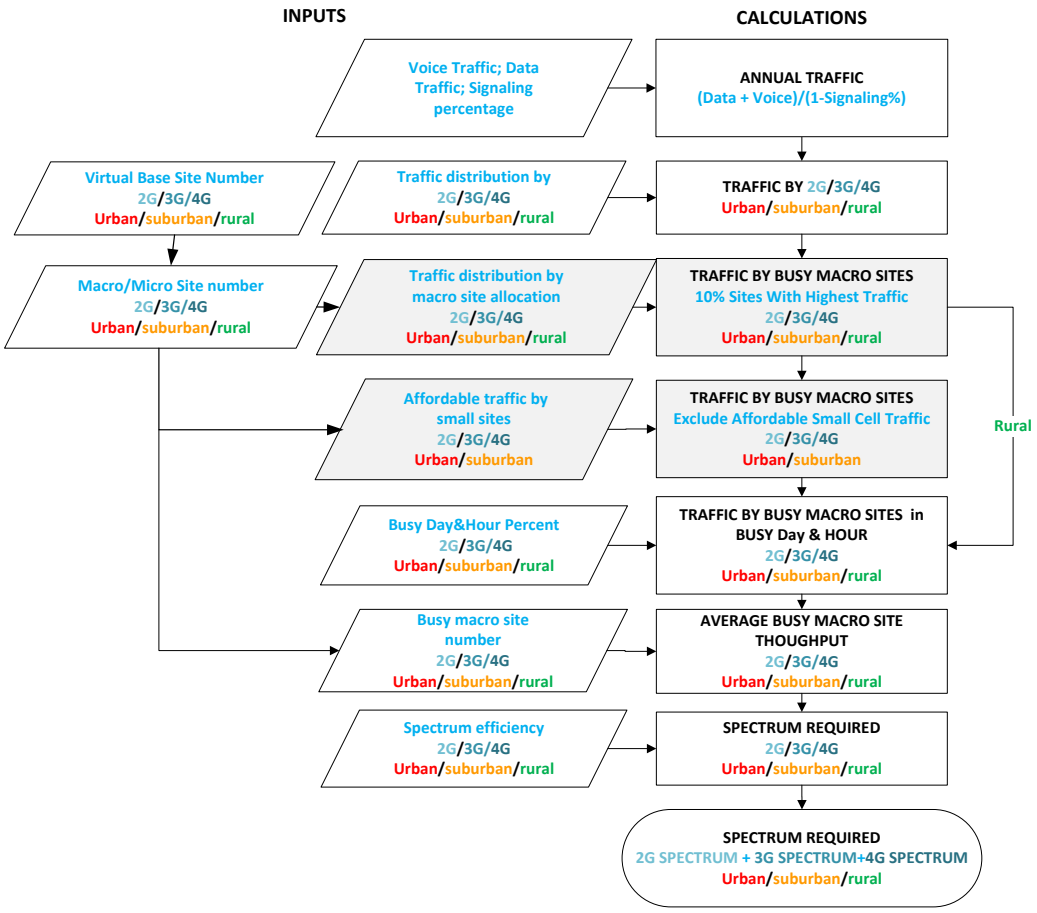
2G Small BSs Distribution Rate among 3 Geotypes													
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
urban	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%
suburban	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
rural	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

3G Small BSs Distribution Rate among 3 Geotypes													
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
urban		100%	100%	98%	90%	90%	80%	80%	80%	80%	80%	80%	80%
suburban		0%	0%	2%	10%	10%	20%	20%	20%	20%	20%	20%	20%
rural		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

4G Small BSs Distribution Rate among 3 Geotypes													
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
urban								100%	98%	90%	80%	80%	80%
suburban								0%	2%	10%	20%	20%	20%
rural								0%	0%	0%	0%	0%	0%

4.4 Traffic Distribution by site allocation

In this section, the calculation steps marked by grey color as below are explained.



4.4.1 Traffic Distribution by macro base stations

Considering that a certain part of cell sites actually carries higher traffic than the others, Table 4-25 provides the estimated traffic distribution by site allocation.

Table 4-25 Traffic Distribution by Site Allocation

Site Percentage	Traffic Proportion (urban)	Traffic Proportion (suburban)	Traffic Proportion (rural)
10%	46%	39%	26%
20%	65%	54%	39%
30%	77%	63%	49%
40%	84%	70%	57%
50%	89%	78%	65%
60%	92%	85%	72%
70%	95%	90%	79%
80%	98%	94%	86%
90%	99%	97%	93%
100%	100%	100%	100%

By using Table 4-25, the traffic of busy macro sites (the top “10 %” site which carry highest traffic) could be calculated. After precluding the affordable traffic by small

base stations shown in section 4.4.2, the remaining traffic over busy macro sites could be obtained.

4.4.2 Affordable Traffic by small base stations

It is assumed that the macro sites with more traffic have more number of small sites to offload. As shown in Table 4-26, the top 10% busier macro sites have 20% small sites to offload traffic.

Table 4-26 Relationship between Macro Site and Small Site

Macro Site Percentage	Small Site Percentage
10%	20%
20%	37%
30%	50%
40%	61%
50%	71%
60%	79%
70%	87%
80%	92%
90%	96%
100%	100%

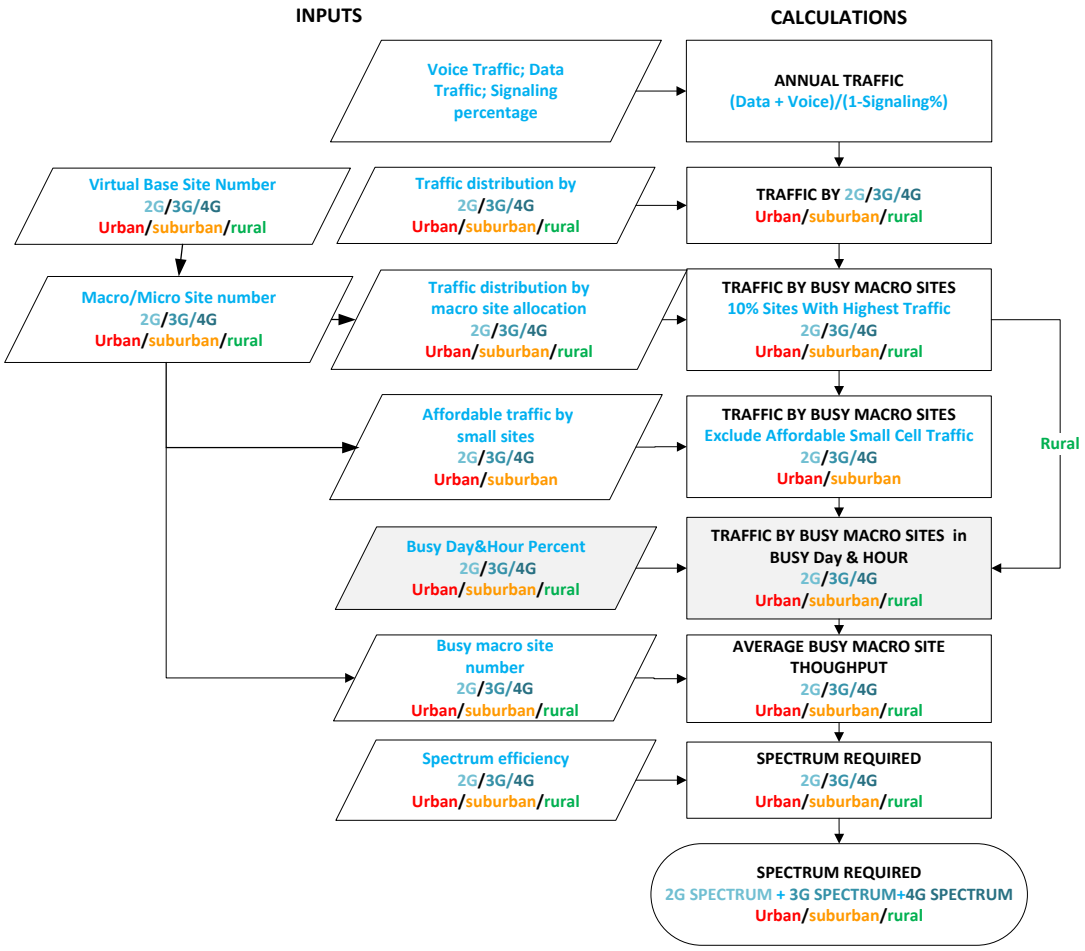
With the relationship shown in Table 4-26, the small site bandwidth shown in Table 4-27, spectrum efficiency shown in Table 4-30, and the maximum load rate of small sites, the affordable traffic by small sites could be calculated.

Table 4-27 Small Site Bandwidth

	Bandwidth
2G	2×0.4 MHz
3G	2×2 MHz
4G	2×10 MHz

4.5 Traffic Distribution by Day and Hour

In this section, the calculation steps marked by grey color as below are explained.



Considering that a certain period of time actually carries higher traffic than other time the whole year traffic needs to be distributed into busy hour as follows:

— Whole year traffic distributed to Busy Day. The whole year 365 days are classified into 5 categories and the first 20% days carrying the most traffic are defined to be Busy Day. Here, Busy Days carry 40% of the annual traffic, as shown in Figure 4-6.

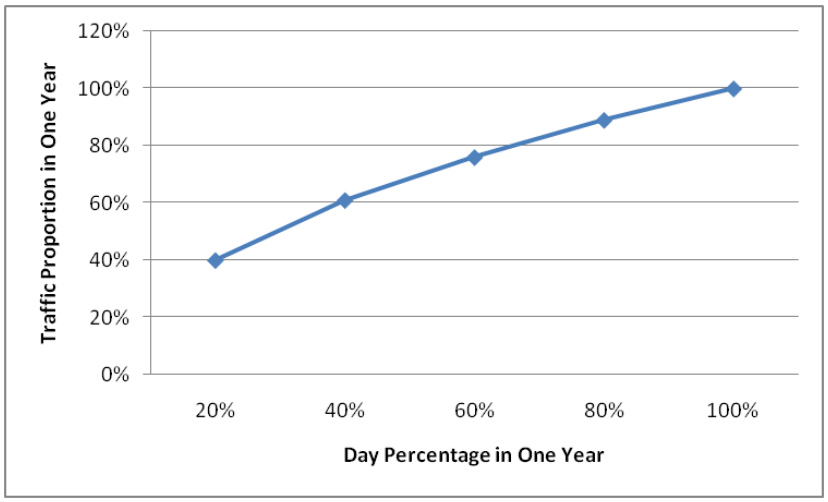


Figure 4-6 Traffic Distributions by Different Days

— Busy day traffic distributed to Busy Hour. Busy hour traffic is assumed to occupy 10% of whole day traffic.

— Traffic per hour transferred to traffic per second. Assuming traffic in 3600 seconds of the busy hour obeys uniform distribution.

4.6 Spectrum Efficiency

Table 4-28 Macro Spectrum Efficiencies of different Technologies

Technology	Spectrum Efficiency (bps/Hz)
EDGE	0.09
WCDMA	0.24
HSDPA R5	0.48
HSPA R6	0.72
HSPA R7	1.29
LTE R8	1.5
LTE-Advanced	2.2

Table 4-28 lists the spectrum efficiencies of different technologies. And the following assumptions are introduced:

— WCDMA is assumed to be used in 2009 and 2010, and it is updated to HSPA R5 after 2010 and to HSPA R6 after 2012.

— LTE R8 is expected to be utilised from 2015 to 2018, and LTE-Advanced is assumed to be utilised after 2018.

— For the better channel propagation environments, the spectrum efficiency of the small base sites is larger than that of macro base sites.

Based on the above assumptions spectrum efficiencies of macro sites and small sites could be estimated as Table 4-29 and Table 4-30.

Table 4-29 Spectrum Efficiency Assumption of the Macro Base Sites

	Spectrum Efficiency												
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
2G	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
3G		0.24	0.24	0.48	0.48	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
4G								1.5	1.5	1.5	1.5	2.2	2.2

Table 4-30 Spectrum Efficiency Assumption of the Small Base Sites

	Spectrum Efficiency												
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
2G	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
3G		0.24	0.24	0.48	0.48	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
4G								4	4	4	4	5	5

4.7 Balance Factor

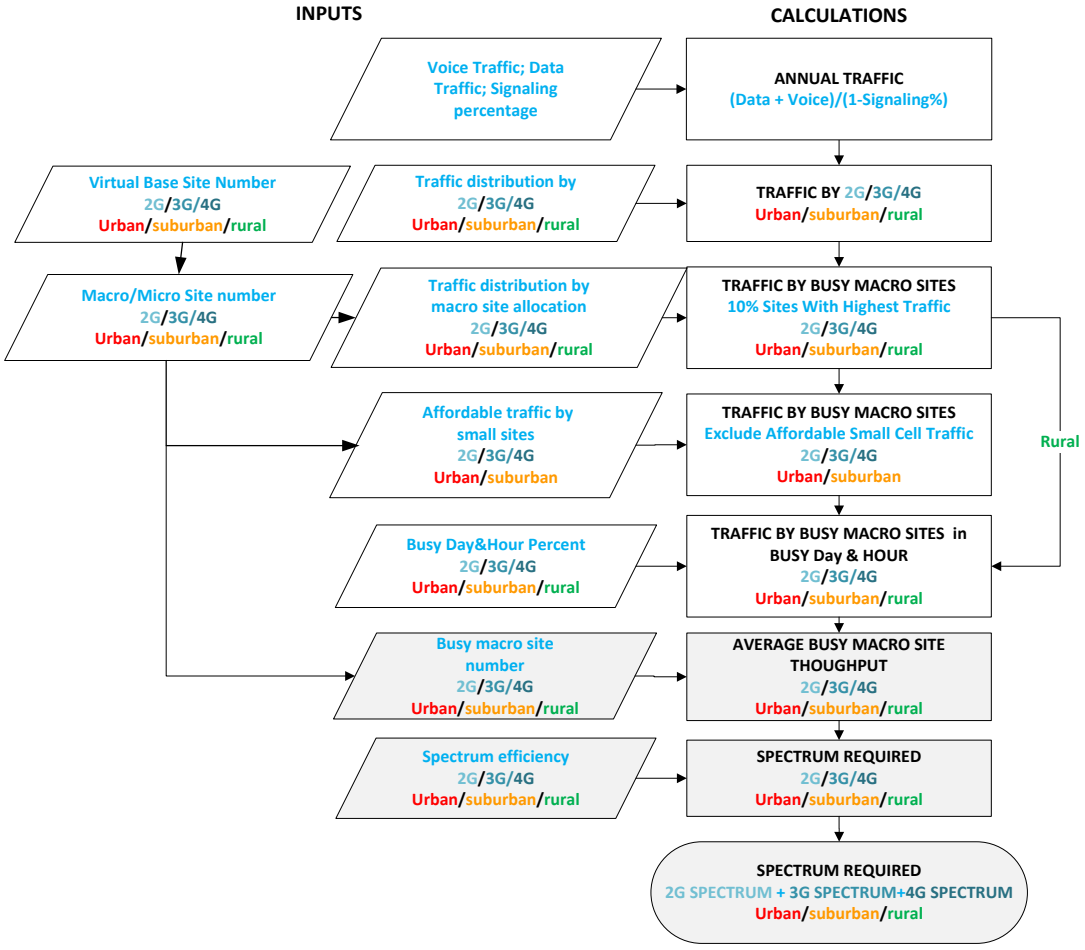
As different operators have different market shares, a parameter of “balance factor” is introduced to give the spectrum margin of each operator which is used in the last step of spectrum estimating.

For example, if the calculated spectrum is T MHz, and the number of operators is N, then the finally spectrum need is (T+(N-1)*BF*T) MHz, where BF is the balance factor.

The balance factor is set to 5%.

4.8 Spectrum Prediction

In this section, the calculation steps marked by grey color as below are explained.



The more detailed procedure is shown in Figure 4-7.

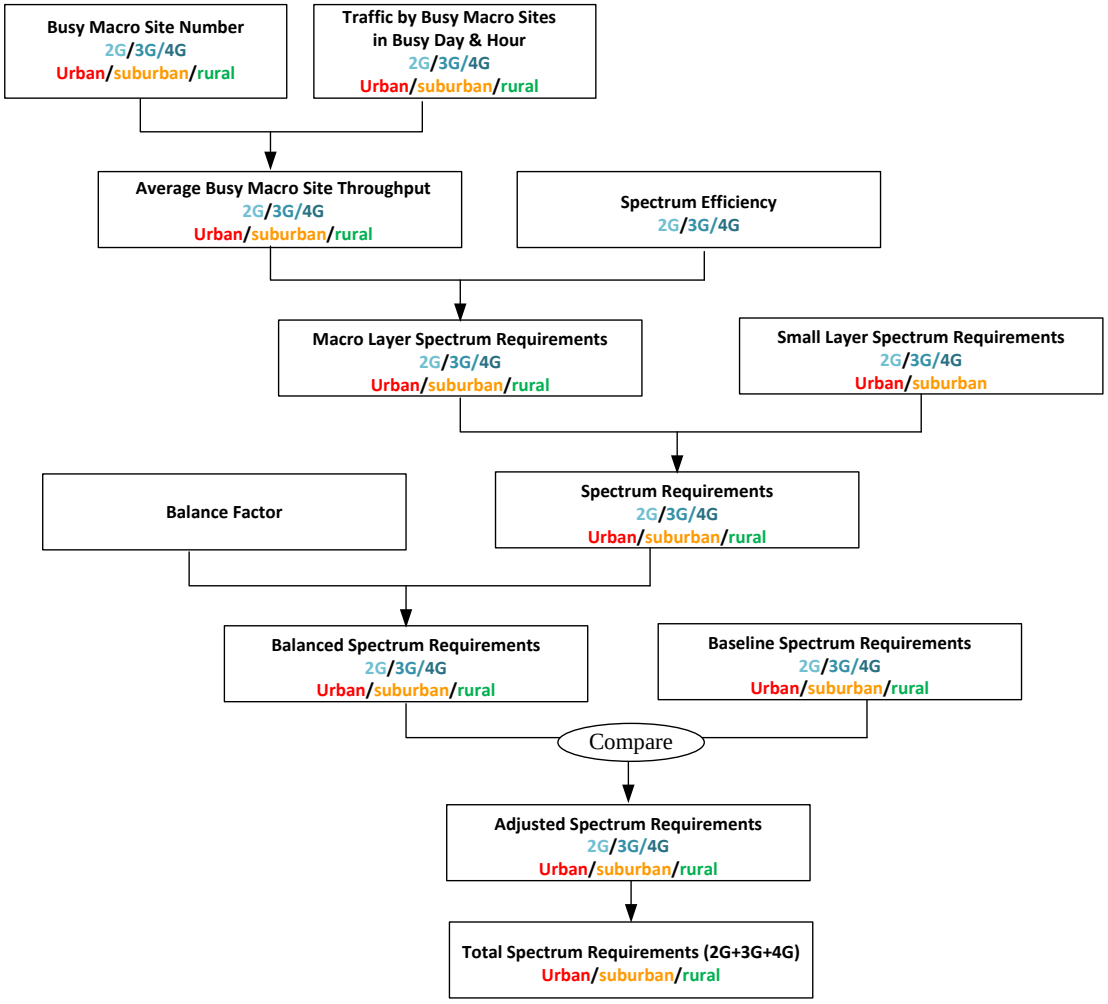


Figure 4-7 Spectrum Prediction Procedure

According to "Traffic By Busy Macro Sites in Busy Day & Hour" calculated as in Section 4.5 and the number of busy macro sites, the average throughput of busy macro sites could be calculated. Further using the spectrum efficiency, the spectrum requirements of macro layer are obtained.

The spectrum requirements of small layer are equivalent to the bandwidth of small sites as shown in Table 4-27.

With spectrum requirements of macro layer and small layer, the network spectrum requirements are calculated by:

- If the macro layer and small layer use the same frequency, the network spectrum requirements are the maximum value of macro layer spectrum requirements and small layer spectrum requirements.
- If the macro layer and small layer use different frequency, the network spectrum requirements are the sum of macro layer spectrum requirements and small layer spectrum requirements.

In this report, same frequency used by macro layer and small layer is assumed.

Balance factor explained in Section 4.7 is used to reflect the margin of spectrum requirements when there is not only one operator.

Because each operator needs to deploy the network with minimum amount of spectrum, the baseline spectrum requirements shown in Table 4-31 are used to adjust the spectrum prediction.

Table 4-31 Baseline Spectrum Requirements

2G	10×N MHz
3G	20×N MHz
4G	40×N MHz
Note: N is the number of operators.	

Finally, the total spectrum requirements are the sum of 2G/3G/4G spectrum requirements.

5. Model Output

5.1 Spectrum Prediction Results

The spectrum requirement is calculated to be 1864 MHz.

Table 5-1 Spectrum Requirements for IMT Systems in China

			urban spectrum requirements						
	2012	2013	2014	2015	2016	2017	2018	2019	2020
2G	169	173	195	195	195	195	195	195	183
3G	60	60	81	125	178	214	312	485	765
4G				120	120	120	257	401	916
Total	229	233	276	440	493	529	764	1081	1864
			suburban spectrum requirements						
	2012	2013	2014	2015	2016	2017	2018	2019	2020
2G	129	132	149	149	149	149	149	149	149
3G	60	60	60	60	64	78	115	180	286
4G				120	120	120	120	166	374
Total	189	192	209	329	333	347	384	495	809
			rural spectrum requirements						
	2012	2013	2014	2015	2016	2017	2018	2019	2020
2G	30	30	30	30	30	30	30	30	30
3G	60	60	60	60	60	60	60	60	30
4G				120	120	120	120	120	120
Total	90	90	90	210	210	210	210	210	180

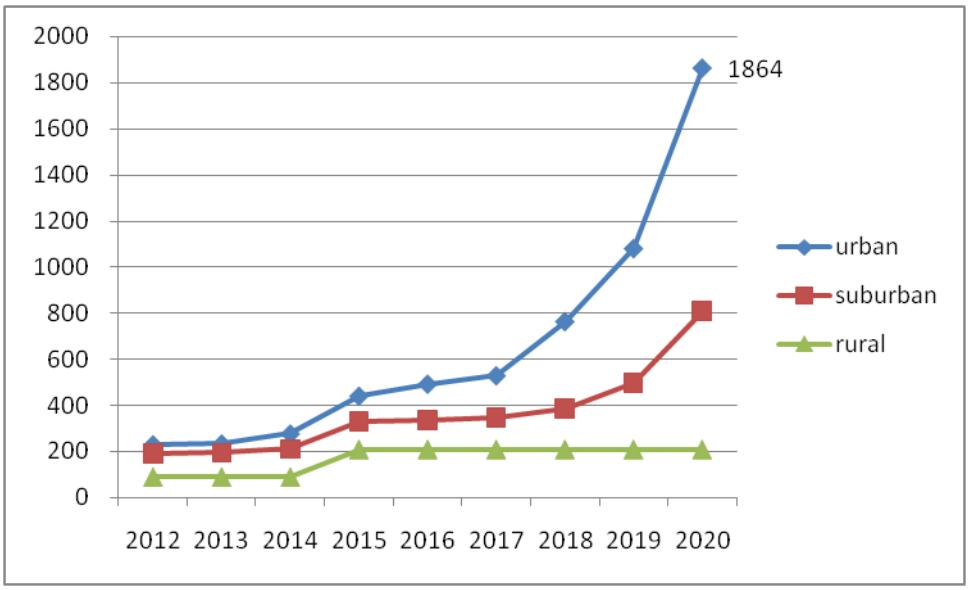


Figure 5-1 Spectrum Requirements for IMT Systems in China

In the rural case, the radius of each cell is assumed to be 5.6km. The best way to achieve this large cell radius is to use the lower spectrum (spectrum below 1 GHz). That means the spectrum prediction results of rural environment are the requirements of spectrum below 1 GHz, which is 210 MHz . If spectrum below 1 GHz cannot be used in rural environment, more base sites need to be deployed to maintain the coverage, and more costs need to be spent.

5.2 Sensitivity Analysis

5.2.1 Sensitivity to Data Traffic Growth Rate

Traffic growth rate is a key factor to the estimation result. Figure 5-2 shows the spectrum requirements with different traffic growth rates assuming data traffic increases of the same rate from 2012 to 2020.

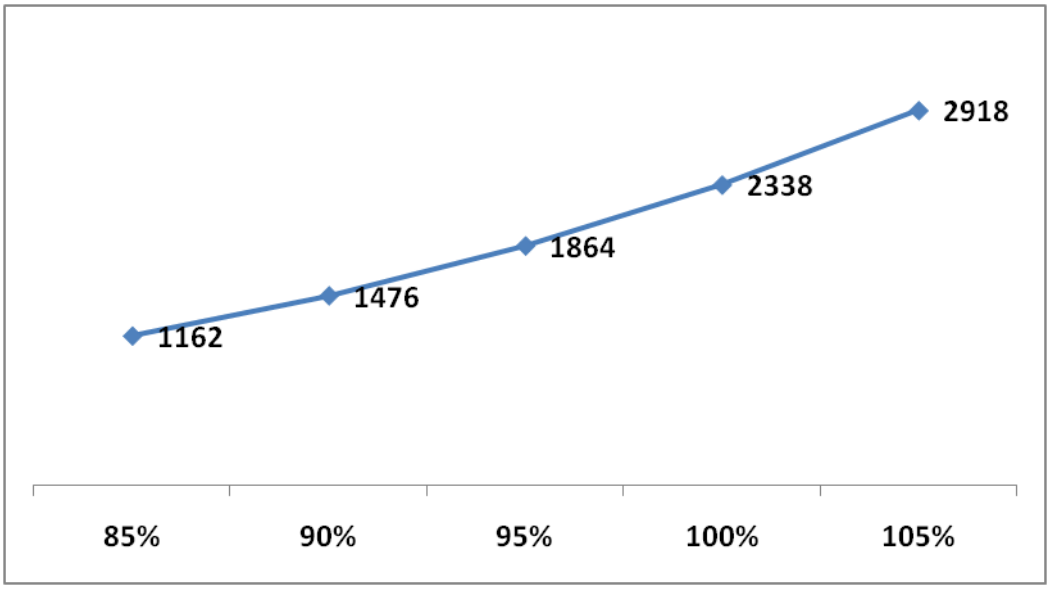


Figure 5-2 2020 Spectrum Requirement Sensitivity of Data Traffic Growth Rate

5.2.2 Sensitivity to Number of Virtual Macro Base Sites

Figure 5-3 shows the spectrum requirements when the number of virtual macro base sites changes from -10% to 10%.

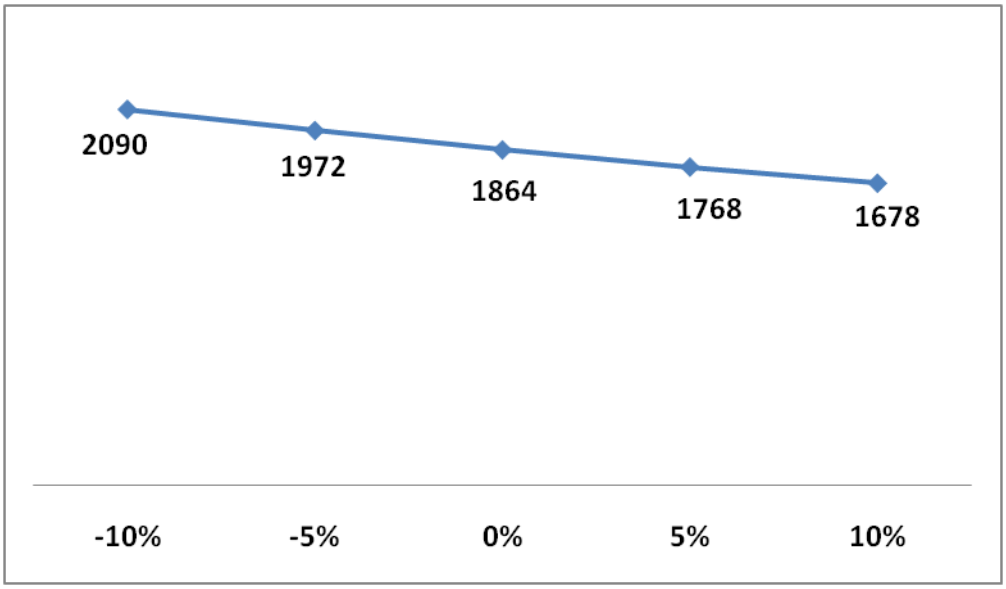


Figure 5-3 2020 Spectrum Requirement Sensitivity of Changing Number of Sites

5.2.3 Sensitivity to Downlink Traffic Percentage of Total Traffic

Figure 5-4 shows the spectrum requirements when the downlink traffic percentage of total traffic changes from 70% to 90%.

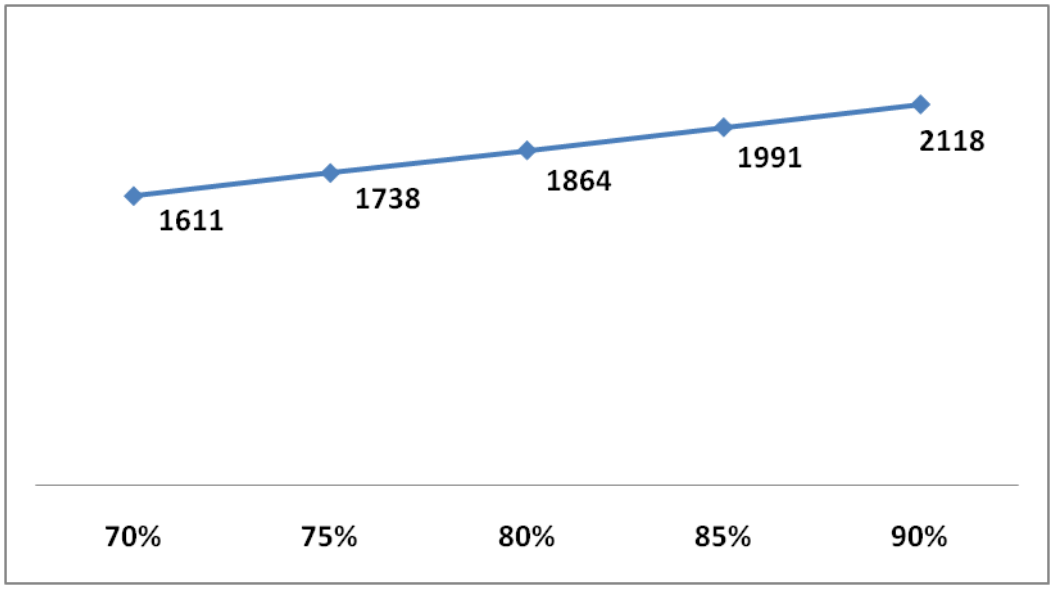


Figure 5-4 2020 Spectrum Requirement Sensitivity of Downlink Traffic Percentage

5.2.4 Sensitivity to Number of Operators

Figure 5-5 shows the spectrum requirements when the number of operators changes from 1 to 5 and the balance factor changes from 3% to 7%.

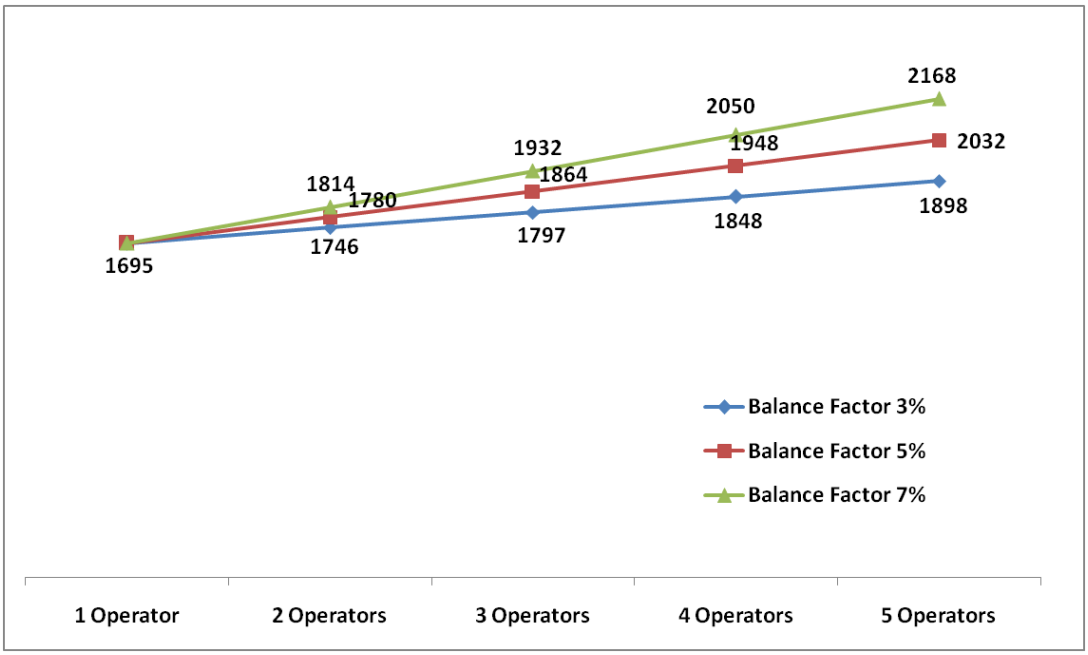


Figure 5-5 Spectrum Requirement Sensitivity of Changing Number of Operators

6. Estimation by Other Approaches

6.1 ITU-R M.1768

6.1.1 Methodology Approach

The detailed methodology for calculating the spectrum requirements for the future development of IMT-2000 and IMT-Advanced is presented in detail in [9]. The methodology has been developed in ITU-R WP8F. And in our project the estimation tool developed by WINNER is utilised.

6.1.2 Methodology flow chart

The flowchart of the spectrum calculation methodology is given in Figure 6-1. More detailed description of the methodology including the equations can be found in [1].

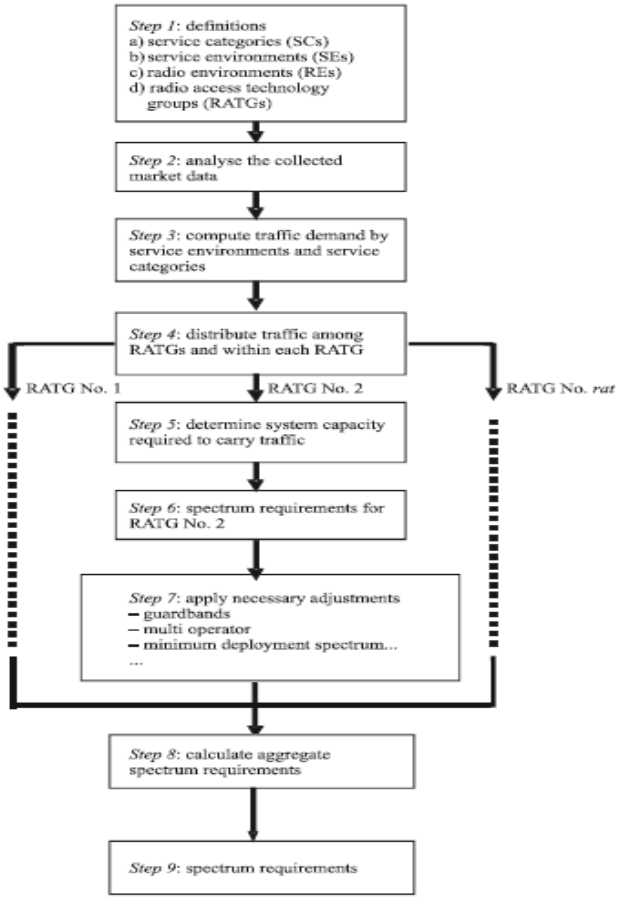


Figure 6-1 Flow Chart of M.1768 Methodology

[9]ITU-R Recommendation M.1768 "Methodology for calculation of spectrum requirements for the future development of the terrestrial component of IMT-2000 and systems beyond IMT-2000"; November 2005

6.1.3 Model Inputs

The parameter values from Report ITU-R M.2078 are used as the starting point and some input parameter values are changed considering the updated market situations and forecasts of China.

The proposed input parameter values are presented for the calculation year 2020 and the calculations using the "WINNER SPECULATOR" tool are only for the year 2020. This can be done by selecting "0" for the year selector in worksheet "Market Studies" for 2010 and 2015 and by selecting "1" for 2020.

Only changes of parameters are shown as follows. Other parameters keep the same with "Speculator_v2 26-Biarritz".

- **Market Input 2020 - User density(users/km^2)**

Based on the development status of China, "Current Value" of user density is modified, lowering the values of suburban and rural while increasing the values of urban as follows.

Table 6-1 "Current Value" of 2020 user density - Downlink

SC	SE	User Density (users/km^2) Current Value	SC	SE	User Density (users/km^2) Current Value	SC	SE	User Density (users/km^2) Current Value	SC	SE	User Density (users/km^2) Current Value
1	1	0	6	1	1743	11	1	55.5	16	1	0
1	2	0	6	2	1743	11	2	66	16	2	52
1	3	0	6	3	2324	11	3	37587.5	16	3	0
1	4	0	6	4	0	11	4	0	16	4	0
1	5	0	6	5	0	11	5	2779.3	16	5	10
1	6	0	6	6	0	11	6	52.1	16	6	0
2	1	9460	7	1	10161	12	1	70282	17	1	8986.5
2	2	34079	7	2	27160	12	2	241640	17	2	32433.5
2	3	20433.5	7	3	5943.5	12	3	164461.5	17	3	5939
2	4	567.6	7	4	366.8	12	4	4209.4	17	4	523.9
2	5	1514.3	7	5	31	12	5	12158.4	17	5	415.6
2	6	28.375	7	6	18.7	12	6	237.075	17	6	26.25
3	1	33081	8	1	31513	13	1	26590.5	18	1	618
3	2	66369	8	2	31619	13	2	26527	18	2	1339
3	3	52439	8	3	42630.5	13	3	35029	18	3	21
3	4	811.8	8	4	21	13	4	32	18	4	103
3	5	2035.5	8	5	52	13	5	103	18	5	72
3	6	37.925	8	6	5	13	6	24	18	6	10
4	1	26127.5	9	1	309	14	1	27939	19	1	515
4	2	26153	9	2	412	14	2	27939	19	2	1030
4	3	34821	9	3	52	14	3	51857.5	19	3	52
4	4	12	9	4	52	14	4	22.7	19	4	52
4	5	21	9	5	103	14	5	1170.3	19	5	52
4	6	13	9	6	10	14	6	22.575	19	6	10
5	1	73091.5	10	1	206	15	1	23189.5	20	1	1030
5	2	134346	10	2	309	15	2	79089.5	20	2	1030
5	3	90663.5	10	3	52	15	3	51010	20	3	103
5	4	1687.7	10	4	52	15	4	1311.6	20	4	103
5	5	3454.6	10	5	52	15	5	3704.9	20	5	52
5	6	83.325	10	6	10	15	6	69.775	20	6	10

Table 6-2 "Current Value" of 2020 user density - Uplink

SC	SE	User Density (users/km^2) Current Value	SC	SE	User Density (users/km^2) Current Value	SC	SE	User Density (users/km^2) Current Value	SC	SE	User Density (users/km^2) Current Value
1	1	0	6	1	1743	11	1	55.5	16	1	0
1	2	0	6	2	1743	11	2	66	16	2	52
1	3	0	6	3	2324	11	3	74	16	3	0
1	4	0	6	4	0	11	4	0	16	4	0
1	5	0	6	5	0	11	5	5	16	5	10
1	6	0	6	6	0	11	6	0	16	6	0
2	1	52	7	1	22733.5	12	1	43931	17	1	632.5
2	2	57	7	2	71484.5	12	2	156553	17	2	1422
2	3	0	7	3	46303	12	3	94524.5	17	3	1096.5
2	4	21	7	4	1121.1	12	4	2605.3	17	4	22.6
2	5	10	7	5	3001.1	12	5	6940	17	5	56.9
2	6	1	7	6	56.425	12	6	130.275	17	6	1.2
3	1	33276.5	8	1	31513	13	1	29582.5	18	1	618
3	2	66600.5	8	2	31619	13	2	26527	18	2	1339
3	3	52470	8	3	42630.5	13	3	35029	18	3	21
3	4	822.1	8	4	21	13	4	206	18	4	103
3	5	2041.2	8	5	52	13	5	103	18	5	72
3	6	37.975	8	6	5	13	6	24	18	6	10
4	1	26127.5	9	1	309	14	1	27939	19	1	515
4	2	26153	9	2	412	14	2	27939	19	2	1030
4	3	34821	9	3	52	14	3	51857.5	19	3	52
4	4	12	9	4	52	14	4	22.7	19	4	52
4	5	21	9	5	103	14	5	1170.3	19	5	52
4	6	13	9	6	10	14	6	22.575	19	6	10
5	1	73091.5	10	1	5663	15	1	62189.5	20	1	1030
5	2	134346	10	2	20170.5	15	2	219489.5	20	2	1030
5	3	90663.5	10	3	12035.5	15	3	131940	20	3	2319.5
5	4	1687.7	10	4	338.9	15	4	3651.6	20	4	103
5	5	3454.6	10	5	894.8	15	5	9699.7	20	5	173.2
5	6	83.325	10	6	16.925	15	6	182.175	20	6	10

- **Parameters for packet-switched service categories - Mean packet delay**

In M.2078 the mean delay requirements less than one millisecond are seen to be too strict from practical radio system point of view for IMT. Given LTE system as an example, the standardized QCI characteristics including the maximum packet delay requirement are given by 3GPP TS 23.203 which shows that even for real time gaming service, a service very sensitive to delay, the packet delay budget is 50ms.

Considering the above discussions mean delay requirements here are updated as Table 6-3 below.

Table 6-3 Mean delay requirements per service category for the year 2020 (unit: ms/packet)

Traffic class / Service type	Conversational	Streaming	Interactive	Background
Super-high multimedia	Treated as reservation-based	Treated as reservation-based	20	100
High multimedia	Treated as reservation-based	Treated as reservation-based	20	100
Medium multimedia	Treated as reservation-based	Treated as reservation-based	20	100
Low rate data and low multimedia	Treated as reservation-based	Treated as reservation-based	20	100
Very low rate data	Treated as reservation-based	Treated as reservation-based	20	100

- **Cell area**

According to the typical Macro cell topology in different teledensity scenarios, the cell coverage area seems to be smaller in M.2078. Thus cell coverage areas are adjusted referring to Section 4.3.4. The updated values are shown in Table 6-4.

Table 6-4 Modified Cell Areas

SECTOR AREA [km^2]			
Radio environment	Teledensity		
	DU	SU	RU
Macro cell	0.22	2.23	21.75
Micro cell	0.07	0.1	0.15
Pico cell	1.60E-03	1.60E-03	1.60E-03
Hot spot	6.50E-05	6.50E-05	6.50E-05

- **Area spectral efficiency**

The area spectral efficiency parameter in M.2078 is seen to be higher than practical IMT systems. According to 3GPP TR 36.912 V9.0.0 and '16.4 Spectral efficiency and user throughput' of it, Macro, Micro and Hotspot spectral efficiencies for RATG #2 can be estimated from '16.4.1.3 Base coverage urban', '16.4.1.2 Microcellular' and '16.4.1.1 Indoor'. And Pico cell spectral efficiency is estimated between the value of Micro and Hotspot.

Besides, values for RATG #1 are estimated in accordance with Section 4.6. The results are illustrated in Table 6-5.

Table 6-5 Adjusted Spectrum Efficiencies

RATG #1				
Teledensity	Radio Deployment Environments			
	Macro cell	Micro cell	Pico cell	Hot Spot
Dense Urban	0.5	0.7	0.9	-
Sub Urban	0.5	0.7	0.9	-
Rural	0.5	0.7	0.9	-

2020

RATG #2				
Teledensity	Radio Deployment Environments			
	Macro cell	Micro cell	Pico cell	Hot Spot
Dense Urban	2.2	3.7	5.2	6.6
Sub Urban	2.2	3.7	5.2	6.6
Rural	2.2	3.7	5.2	6.6

- **Radio-related input parameters – "Minimum deployment per operator per radio environment" and "mobile multicast modes by RATG1"**

"Minimum deployment per operator per radio environment" describes the minimum amount of spectrum needed by an operator to build a practical network with given RATG technology for a given radio environment. The values of it in M.2078 for RATG 1 are relatively high compared to the currently envisaged deployment. Thus the parameters are to be reduced while ensuring that the application data rate can be supported in the given radio environment with the given area spectral efficiencies.

In addition, multicast services are not and will not be supported by RATG1. The value of "Support for multicast" for RAGT 1 is changed to "0".

The adjusted values are shown in Table 6-6.

Table 6-6 Adjusted Radio Parameters

Required Radio Parameters for RATG #1					
Attribute	Unit	Value			
		Macro cell	Micro cell	Pico cell	Hot spot
Application data rate	[kbit/s]	20000	40000	40000	0
Maximum supported velocity	[km/h]	250	50	4	0
Guard band between operators	[MHz]	0			
Minimum deployment per operator and radio environment	[MHz]	20	20	20	0
Number of overlapping network deployment	#	1			
Support for multicast (yes=1, no=0)		0			

Required Radio Parameters for RATG #2					
Attribute	Unit	Value			
		Macro cell	Micro cell	Pico cell	Hot spot
Application data rate	[kbit/s]	0	0	0	0
Maximum supported velocity	[km/h]	250	50	4	4
Guard band between operators	[MHz]	0			
Minimum deployment per operator and radio environment	[MHz]	20	20	20	20
Number of overlapping network deployment	#	1			
Support for multicast (yes=1, no=0)		1			

- **Revision of M.1768 Model – Applying some adjustment-step 3**

According to WP5D #14th meeting an adjustment is taken as follows:

$$F_{d,t,rat} = \max\left(F_{d,t,rat,macro}, F_{d,t,rat,micro}\right) + \max\left(F_{d,t,rat,pico}, F_{d,t,rat,hotspot}\right) \quad (1)$$

6.1.4 Model Output

By using updated input parameter values described above, the estimated spectrum requirement of IMT systems can be calculated using the tool for 2020. About 1,860 MHz in total would be required. It can be seen that this result is compatible with the output of CATR Model in Section 5.1.

Table 6-7 Spectrum Requirement for IMT at 2020

Total Spectrum Requirements for all Deployments, including Guardband Adjustment - RAT Group #1 (MHz)			
Teledensity	year 2010	year 2015	year 2020
Dense Urban	0	0	840
Sub Urban	0	0	420
Rural	0	0	240

Total Spectrum Requirements for all Deployments, including Guardband Adjustment - RAT Group #2 (MHz)			
Teledensity	year 2010	year 2015	year 2020
Dense Urban	0	0	1 020
Sub Urban	0	0	480
Rural	0	0	180

Final Spectrum Requirements (MHz)			
Spectrum for RATG	year 2010	year 2015	year 2020
RAT Group #1	0	0	840
RAT Group #2	0	0	1 020

6.2 FCC of USA

6.2.1 Methodology Approach

The basic idea of this approach is to utilise trends such as fast growing mobile data traffic, the increasing number of cell sites and the improvement of spectrum efficiency. By adjusting the expected growth in data demand for offsetting growth in network density (which is the result of adding new cell sites) and spectral efficiency, future spectrum needs can be forecasted relative to a baseline index of current spectrum in use.

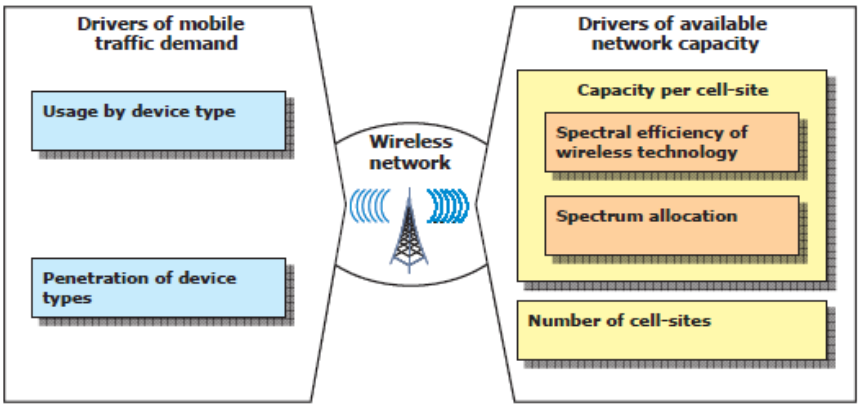


Figure 6-2 Drivers of mobile traffic demand and mobile network capacity

The important beginning is to analyse the drivers of mobile traffic demand and total available network capacity, as illustrated in Figure 6-2. New spectrum is substitutable, to a point, to build new cell-sites and develop and implement more efficient wireless technologies. The detailed methodology for calculating the spectrum requirements for mobile broadband is presented in detail in [10].

6.2.2 Methodology flow chart

The flow chart of the spectrum calculation methodology is given in Figure 6-3. The steps are explained in following sections. Future spectrum needs can be understood as a function, or multiplier, of current spectrum used for mobile broadband nationwide. The multiplier is based on an average of reputable industry analyst mobile data demand forecasts, adjusted to account for additional network density via cell site growth and improvements in technology resulting in increased spectral efficiency. More detailed description of the methodology can be found in [2].

It should be noted that the baseline is changed to 2011 in our project.

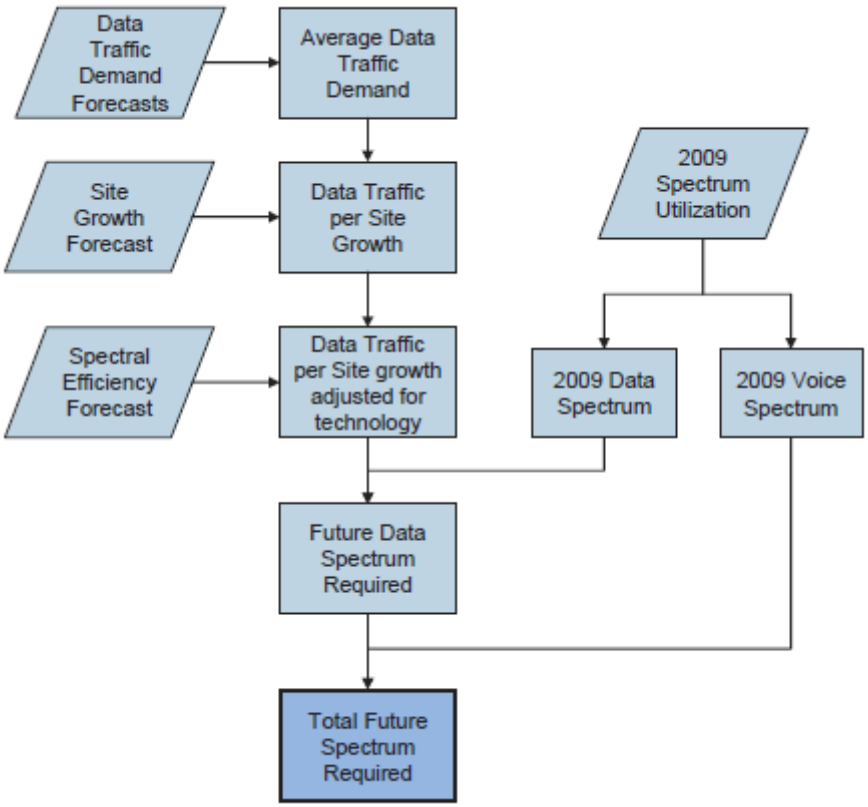


Figure 6-3 Top-Down Forecast Flowchart

[10]Federal Communications Commission "Mobile Broadband: The Benefits of Additional Broadband " OBI Technical Paper Series, October 2010

6.2.3 Model Inputs

- **Data Traffic Forecast**

Data traffic forecast keeps the same with section 4.1.2, as shown in Table 6-8.

Table 6-8 Data Traffic Forecast

Description	Data Traffic (KTB/year)	Cell Site Growth Raletive to 2011
2011	318.03621	100%
2012	678.960196	213.49%
2013	1427.64723	448.89%
2014	2962.25544	931.42%
2015	6077.10186	1910.82%
2016	12349.7564	3883.13%
2017	24903.1357	7830.28%
2018	49904.009	15691.30%
2019	99507.2503	31288.03%
2020	197637.457	62143.07%

- **Cell Site Growth Forecast**

Considering the huge number of cell sites in China so far, the primary purpose of building new cell sites is not to expand coverage but to increase capacity, mostly fulfilled by small cells, the so-called “infill” sites. Besides, a considerable part of new 3G and 4G base stations are site-sharing with existing 2G base stations. Therefore, the overall cell sites growth can be approximated by the increase of small 2G base stations.

Table 6-9 below illustrates the compound annual growth rate (CAGR) of small base stations of different technologies. And according to the above analysis 13.65%, CAGR of small 2G base stations, can be seemed as the CAGR of overall cell sites.

Table 6-9 Compound Annual Growth Rate of Small Base Stations

YEAR	2G Small	3G Small	4G Small	2G CAGR	3G CAGR	4G CAGR
2011	197500	63300		13.65%	19.33%	
2012	259375	111867				
2013	308050	152663				
2014	329467	189379				
2015	329467	226911	0			
2016	329467	247554	10833			
2017	329467	271938	33521			
2018	329467	288154	67621			
2019	329467	299289	97458			
2020	329467	310646	129683			86.01%

- **Spectrum Efficiency Forecast**

According to Section 4.6 and Section 4.3.1, the weighted average spectrum efficiency can be calculated by “Table 4-29 Spectrum Efficiency for 2G/3G/3G”, with the

weights of “Table 4-18 Numbers of Base Stations of 2G/3G/4G”. The results are shown as follows.

Table 6-10 Average Spectrum Efficiency Estimation

YEAR	Weighted Average Spectrum Efficiency	Growth Relative to 2011
2011	0.39	100%
2012	0.43	110.22%
2013	0.61	156.68%
2014	0.68	173.12%
2015	0.79	203.76%
2016	0.88	224.50%
2017	0.97	248.17%
2018	1.09	280.54%
2019	1.18	303.22%
2020	1.61	411.44%

- **Spectrum in Use**

Currently China has assigned 327MHz for IMT systems. It is assumed that 75% of the spectrum is actually utilised, thus 245MHz in use.

6.2.4 Tables of Results

The results of spectrum requirement are illustrated in Table 6-11 below. And in total 1848 MHz spectrum would be required by IMT system in 2020. It can be noticed that this result is compatible as well with the output of CATR Model in Section 5.1.

Table 6-11 Spectrum Requirement Estimation of FCC Model

Line	Description	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	Data Traffic Estimation(KTB/year)	318.0362	678.9602	1427.6472	2962.2554	6077.10186	12349.7564	24903.1357	49904.009	99507.25026	197637.4568
1	**Data growth raletive to 2011**	**100%**	213.49%	448.89%	931.42%	1910.82%	3883.13%	7830.28%	15691.30%	31288.03%	62143.07%
2	Cell Sites										
3	Absolute Growth	100%	114%	129%	147%	167%	190%	215%	245%	278%	316%
4	CAGR	**13.65%**									
5	**Traffic per Site-growth**	**100%**	**187.84%**	**347.54%**	**634.51%**	**1145.36%**	**2048.02%**	**3633.80%**	**6407.27%**	**11241.46%**	**19645.71%**
6	avg. Spectral Efficiency(Mbps/Mhz)	0.39	0.43	0.61	0.68	0.79	0.88	0.97	1.09	1.18	1.61
7	Absolute Growth	100%	110.22%	156.68%	173.12%	203.76%	224.50%	248.17%	280.54%	303.22%	411.44%
8	**Tech-Adjusted Traffic per Site - Growth**	**100%**	**170.43%**	**221.82%**	**366.52%**	**562.11%**	**912.25%**	**1464.21%**	**2283.93%**	**3707.42%**	**4774.92%**
9	Spectrum req'd for data(MHz)	34	58	76	126	193	313	502	783	1272	1638
10	Percent allocated for data	14%	21.72%	26.53%	37.37%	47.78%	59.76%	70.45%	78.80%	85.79%	88.60%
11	spectrum req'd for voice(MHz)	211	211	211	211	211	211	211	211	211	211
12	Percent allocated for voice	86.00%	78.28%	73.47%	62.63%	52.22%	40.24%	29.55%	21.20%	14.21%	11.40%
13	**Spectrum - in Use(MHz)**	**245**	**269**	**287**	**336**	**404**	**524**	**713**	**994**	**1482**	**1848**
14	Spectrum - Currently Allocated (MHz)	327	327	327	327	327	327	327	327	327	327
15	**Surplus/Deficit(MHz)**	**-82.0**	**-57.8**	**-40.2**	**9.4**	**76.5**	**196.6**	**385.9**	**667.1**	**1155.3**	**1521.5**

7. Suitable Frequency Bands under Consideration

7.1 Spectrum below 1 GHz

Based on the output of Section 5.1 and the analysis of Section 5.2 it can be deduced that by 2020 IMT services would require at least 200 MHz spectrum below 1 GHz. Currently spectrum below 1 GHz has been completely identified in China while IMT services only obtained 825-835MHz and 870-960MHz, 100 MHz in total, which means another 100 MHz would be required by 2020.

It is known that the “digital dividend” bands, around 700 and 800 MHz with perfect radio transmission characteristics released from analogue to digital TV transition, is well utilized by LTE services in many countries. If China could allow re-allocating 700MHz band to IMT services the problem here would be perfectly resolved.

7.2 Suitable Frequency Bands under Consideration

With the establishment of the WRC-15 agenda item 1.1 study group in China, some preliminary surveys and analysis have been conducted. And there would be more technical demonstration, co-existence analysis and inter-industry coordination and discussion in the near future. Currently the frequency bands being considered for potential future use by IMT services are listed in Table 7-1.

Table 7-1 Frequency Bands under Consideration for IMT in China

Bands initially considered
606-698 MHz
1427-1518 MHz
1695-1710 MHz
2700-2900MHz
2900-3100 MHz
3100-3300 MHz
3300-3400 MHz
3600-3700 MHz
4400-4500 MHz
4500-4800 MHz
4800-4990 MHz
5350-5470 MHz
5850-5925 MHz
5925-6425 MHz

8. Conclusion

IMT services are experiencing considerable growth in China, mainly driven by consumer demand for mobile data. This report indicates that the maximum data traffic from IMT services in 2020 would achieve nearly 200 Mega-Tera-Byte per year, about 600 times of 2011. And even more base sites would be constantly deployed with CAGR of around 13.65% and the average spectrum efficiency of 2020 would be more than 4 times of that of 2011, it still could not comparable to the increase of data traffic, accordingly the spectrum bandwidth requirement.

The result demonstrates that around 1800 MHz spectrum is likely required from IMT services by 2020 . Looking back to Table 2-1, Section 2.1, currently China has allocated 687 MHz frequency for IMT systems so that approximately over 1100 MHz spectrum deficit would appear by 2020.

Annex 1 Introducing of Virtual Base Site

A concept of virtual base site is introduced in our methodology in order to resolve the following issues.

✧ **Issue**

Generally, base stations of different operators in China do not share the same sites. In another word, different operator's base stations locate on different sites. The ideal spectrum estimation was to calculate the spectrum requirement for each operator in terms of their average site traffic. As utilising different spectrums the whole requirement would be the sum of all operators' spectrums.

To simplify and generalise the method, however, our approach is designed in the perspective of whole mobile traffic accordingly the whole spectrum requirement instead of calculating requirement for each operator respectively, which brings about a problem of reducing spectrum requirement when simply considering total base station number and total mobile traffic of China. This is because:

Supposing the three operators have the same traffic T_1 and the same base station number N_1, thus the total traffic is $3T_1$ and total base station number is $3N_1$. Therefore the average base station traffic is:

$$T_{Av} = \frac{T}{N} = \frac{T_1}{N_1}$$

And spectrum requirement is: (SE indicates spectrum efficiency)

$$SR = \frac{T_{Av}}{SE}$$

Actually since different operator should use different spectrums, the correct requirement should be:

$$SR = \frac{\left(\frac{T_1}{N_1} + \frac{T_1}{N_1} + \frac{T_1}{N_1}\right)}{SE} = \frac{3T_{Av}}{SE}$$

The reason why the two results are different is that averaging the whole traffic by the whole base stations means different operators can work with the same spectrum which is incompatible with the actual situation.

✧ **Solution**

Regarding the issue above, we introduce the concept of "virtual base site". Virtual base site is a logical super site that could absorb all traffic from different operators in a certain area.

— In each network layer (macro/small layer), base stations of different operators with similar coverage could be generalised to one virtual base site though they may do not share one site in the actual network, which is shown in Figure A-1.

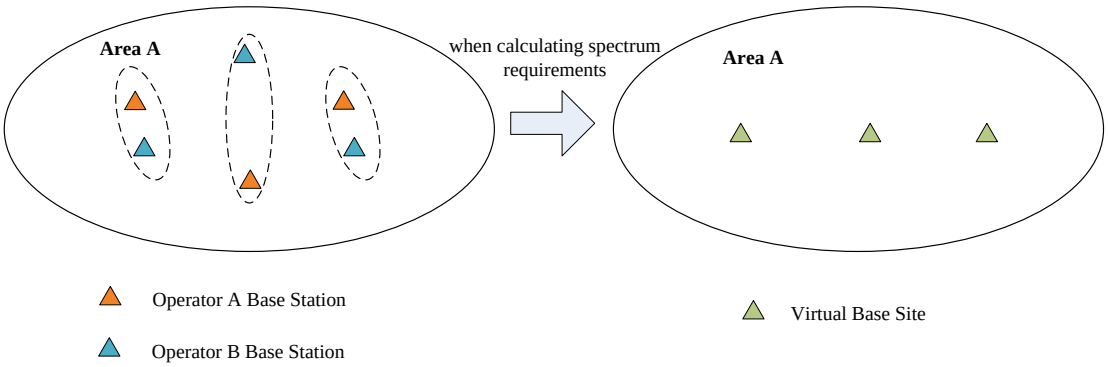


Figure A-1 Concept of Virtual Base Site

— From another perspective, when the total traffic remains unchanged, the spectrum requirements of *N* operators covering similar coverage with similar frequency bands and similar base stations is equivalent to the spectrum requirements of one operator (if the minimum spectrum deployment per operator is not considered).

Annex 2 Voice Minutes to Voice Traffic Conversion (MATLAB Program)

```
clear
Total_Voice_Traffic=86998.36  %% 总话务量  %单位：亿分钟
Voice_Interval=[1:21]; % 通话在1...20分钟以内,最后一个表示通话在20分钟以上
Voice_Interval_Percentage=[0.4,0.3,0.14,0.07,0.04,0.02,0.0085,0.0043,0.0032,0.0012*ones(1,11),0.0009];  %通话量在Voice_Interval中所占的比例
Voice_Interval_Traffic=Total_Voice_Traffic*Voice_Interval_Percentage;
Voice_Interval_Traffic_Adjusted=zeros(1,length(Voice_Interval));
for i1=1:length(Voice_Interval)
    if i1==1
        Voice_temp=Voice_Interval_Traffic(i1);  %处于1分钟以内的通话总量
        Voice_times=Voice_temp;  %通话次数 单位：亿次
        Probability=[1/(45*30)*[1:29],1/45*ones(1,31)];   %通话次数的分布概率:前30秒服从递增的线性分布,后30秒服从均匀分布
        Voice_temp_adjusted=0;
        for i2=1:60
            Voice_temp_adjusted=Voice_temp_adjusted+Voice_times*Probability(i2)*i2/60;  %单位：亿分钟
        end
        Voice_Interval_Traffic_Adjusted(i1)=Voice_temp_adjusted;
    end;
    if i1~=1 && i1~= length(Voice_Interval)
        Voice_temp=Voice_Interval_Traffic(i1);  %处于i1分钟以内的通话总量
        Voice_times=Voice_temp/i1;  %通话次数 单位：亿次
        Probability=1/60*ones(1,60);   %通话次数的分布概率:均匀分布
        Voice_temp_adjusted=0;
        for i2=1:60
            Voice_temp_adjusted=Voice_temp_adjusted+Voice_times*Probability(i2)*((i1-1)+i2/60);  %单位：亿分钟
        end
        Voice_Interval_Traffic_Adjusted(i1)=Voice_temp_adjusted;
    end
    if i1==length(Voice_Interval)
        Voice_temp=Voice_Interval_Traffic(i1);
        Probability=1/(40*80)*[80:-1:1];   %假设超过20分钟的通话在20分钟至100分钟内服从递减的线性分布;
        Voice_temp_adjusted=0;
        for i2=1:length(Probability)
            temp=Voice_temp*Probability(i2);
            Voice_times=temp/(20+i2); %在第i2+20分钟内发生的通话次数
            Probability_one_second=1/60*ones(1,60);   %%在第i2+20分钟内通话结束服从均匀分布
            for i3=1:60
                Voice_temp_adjusted=Voice_temp_adjusted+Voice_times*Probability_one_second(i3)*((i2+20-1)+i3/60);  %单位：亿分钟
            end
        end
        Voice_Interval_Traffic_Adjusted(i1)=Voice_temp_adjusted;
    end;
end
Total_Voice_Adjusted=sum(Voice_Interval_Traffic_Adjusted);
```