

Mobile Traffic Assessment for 4G Network: Virtual Sample Region Approach

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Abstract—As service traffic increases in cellular networks, the mobile network must expand their system capacity. It is important to balance between the volume of mobile traffic and the capacity of mobile system in terms of user experience and operation cost. There are two approaches to assess the balance of demand and supply in cellular network: single cell and national wide scale. Nevertheless, both methods are insufficient to evaluate the balance reasonably in real cellular network in terms of scale: too narrow or wide. As radio resources cannot be exchanged between cells, network operators must perform statistical management on traffic dense areas. This paper introduces the virtual sample region concept that is composed of set of traffic-intensive cells in metropolitan area. We evaluate mobile traffic and system capacity based on real measurement from live 4G system in Seoul, South Korea. In this paper we provide the measurement results of mobile traffic per 10 MHz in real top 10% traffic-intensive cells about 3 years. We also estimate spectral efficiency of virtual sample region using system level simulation, and evaluate system capacity using spectral reuse factor, 4G spectrum bandwidth, simulated spectral efficiency. The margin of 4G system capacity is estimated about 30% in the last three years.

Keywords— mobile traffic, cellular system capacity, network virtualization, network management

I. INTRODUCTION

The demand of mobile service shows dramatic increment. According to Cisco's Visual Networking Index (VNI) Report 2019[1], the global IP traffic will reach 396 exa-bytes per month by 2022, which is 3.3 times of its 2017 level. Mobile Network Operator(MNO) must expand their system capacity to maintain the balance between mobile traffic volume and system capacity in terms of user experience and operation cost. To perform this, the volume of service traffic is measured from mobile network statistics, and the capacity of mobile system is evaluated from network parameters which are spectrum bandwidth, spectrum reuse factor, and spectral efficiency. Network capacity can be estimated as the product of spectrum bandwidth, spectral efficiency[2], and spectrum reuse factor(i.e. the number of cells). There are two approaches to assess mobile network capacity: single cell and national wide scale. ITU-R recommendation[3] describes the method of evaluate system capacity and spectrum requirement for single cell. Although it derives system capacity from required service traffic and traffic characteristics(i.e. QoS parameters), this method has a

limitation of the analysis on a single cell scale without taking into account the statistical characteristics of the network. On the other hands system capacity assessment on a national scale has an over-estimated issue. In general MNOs have two perceptive in their network planning: coverage and capacity. They deploy cells(i.e. the base stations) not only to expand the capacity in dense area but also to extend coverage in rural area, even if there is no shortage of capacity. This deployment of cell for coverage expansion causes nominal increment of system capacity on a national scale. But network capacity and radio resource is regionally limited capability and difficult to be exchanged between cells. Network capacity should be addressed from a regional perspective for traffic-intensive areas.

In this paper, we introduce the virtual sample region(VSR) model which consists of upper 10% traffic-intensive cells in metropolitan area. We quantify the system capacity and traffic volume and evaluate the balance between the traffic volume and system capacity in the VSR based on real measurement from live 4G system in Seoul, South Korea. We provide the measurement of mobile traffic per 10 MHz in VSR and evaluate system capacity using 4G spectrum bandwidth, estimated spectral efficiency, and spectral reuse factor from March 2017 to March 2019.

II. RELATED WORK

While the amount of traffic can be measured from real network usage statistics of mobile operator, the capacity of network should be estimated by several network parameters. The parameters for assessing network capacity consist of three general categories: radio spectrum bandwidth; geographic spectrum reuse; and spectral efficiency of radio access technology[2]. In [4], Real Wireless assessed the mobile capacity and analyses the balance between growing demand for wireless broadband capacity for 700 MHz in UK. R. N. Clarke evaluated the capabilities of 4G LTE network and demand of traffic in US, and described network capacity index and traffic demand index considering factors of technological development from 2010 to 2022 in [2]. E. Oughton et al. introduced scenario-based assessment of the future supply and demand for mobile telecommunications infrastructure in [5], which considers not only technology but also demographics effect. But these analyses were performed on a national-wide scale. On the other hands, Reference [6] introduce the method

LTE spectrum saturation using virtual site concept and effective resource block(ERB). It is also limited to saturation analysis on a single cell scale.

III. ANALYSIS OF MOBILE TRAFFIC ON VIRTUAL SAMPLE REGION

A. Concept of Virtual Sample Region

In this section, we introduce the virtual sample region(VSR) model to estimate the balance between traffic volume and system capacity. As mentioned in introduction, the analysis on single cell or national-wide scale has limitations in scale perspective. MNO needs to manage traffic and capacity at the network scale for traffic-intensive regions.

For this purpose, we defined cells with the upper 10% of RBs utilization as sample cells for each band in interested metropolitan area. Then we defined a virtual area composed of sample cells for every band as VSR. The VSR concept is shown in Fig.2. In Fig.2 blue line circles represents sample cells in band 1(ex. 800 MHz) and red circles means band 2's sample cells(ex. 1800 MHz). Each band has different bandwidth and the number of cell. As the height of plate represents the bandwidth of each band in Fig.2, each area of band composed of multiple cells represent the proportion of capacity of each band in VSR.

We derived the system capacity as product of spectrum bandwidth(MHz), spectral efficiency(bps/MHz), and spectrum reuse factor. Let there be M bands with respective bandwidths $\{B_1, \dots, B_M\}$, M spectral efficiencies $\{E_1, \dots, E_M\}$, and M the number of cells $\{N_1, \dots, N_M\}$. We derive the system capacity C of VSR as shown in Equation (1). The traffic volume T in VSR is also derived by Equation (1) where T_m is measured traffic volume of each band.

$$C = \sum_m B_m E_m N_m, \quad T = \sum_m T_m \quad (1)$$

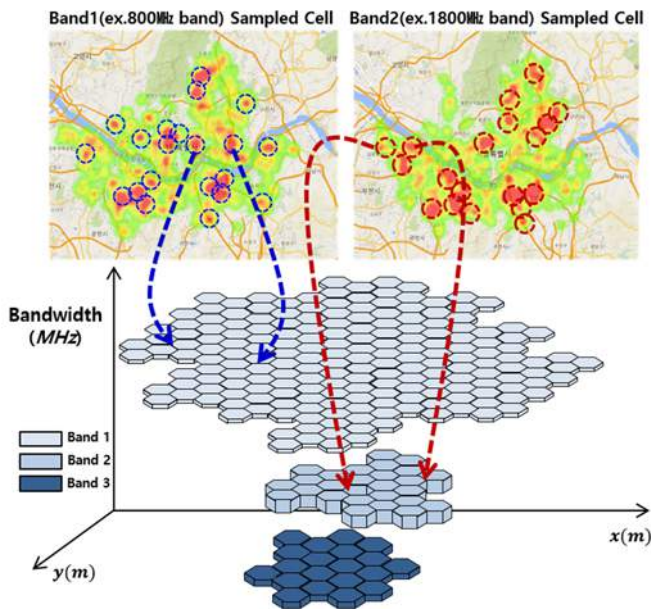


Figure 1. The concept of virtual sample region



Figure 2. The growth of 4G traffic volume in VSR

B. Growth in traffic volume(Demand)

The trends of mobile service demand in Korea has been one of continuous and rapid growth. The growth in 4G mobile traffic in VSR is shown in Fig.3. We used real measurement data of upper 10% RB utilization cells from Mar. 2017 to Mar. 2019 in Seoul, Korea. We used only 4G network as traffic of 4G network accounted for 99.81% of the total mobile traffic in 2017 and the rate is increasing. We also analyse only downlink data as network saturation mainly occurs in downlink traffic in FDD system. We derived quarterly averages for monthly data.

C. System Capacity parameter(Supply)

System capacity is expressed as product of spectrum bandwidth, spectral efficiency, and spectrum reuse factor(i.e. the number of cells). In this section we derive numerical value of each parameter to evaluate system capacity.

1) Spectrum bandwidth: Total 12 downlink band and 170 MHz downlink bandwidth were supplied to MNOs in Korea from 2017 to 2018, and in early 2019 additional 5 MHz bandwidth were added from 3G to 4G system.

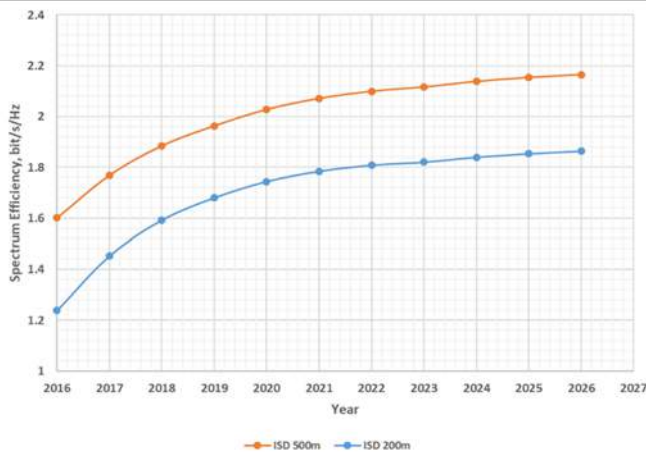
Table 1. Spectrum Supply in Korea as of February 2019(MHz)

Year	Uplink	Downlink	Total
2017	160	170	330
2018	160	170	330
2019	165	175	340

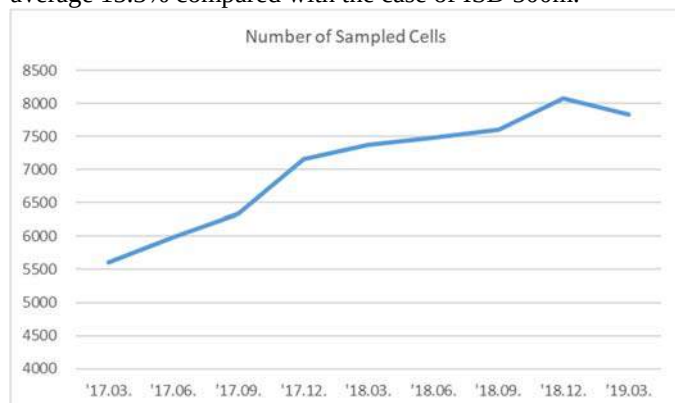
2) Spectral Efficiency: We used simulated spectral efficiency by system level simulation(SLS) instead of measured efficiency as it can change over time and the environment. The LTE-A SLS for spectral efficiency is introduced [7]. In this paper the inter-sight distance(ISD) was defined 500m for typical cell deployment. As this ISD value is not suitable for the cell dense area in VSR, we redefined this value to 200m while other parameters were kept. We also developed 256 QAM function and combined it with the Vienna simulator as it does not support 256 Quadrature Amplitude Modulation(QAM) modules[8], [9].

Table 2. 4G System level simulation parameters

Parameter	Value
Inter site distance	200m
The number of cell	57(2-tier, 19 site with 3sector)
The number of active user	570(10 per BS)
Frequency	2.1 GHz
Bandwidth	10 MHz
Antenna configuration	1x1, 2x2, 4x2, 4x4
Transmission mode	1,2,3,4
Channel feedback delay	3m
Channel model	3GPP urban area
Minimum coupling loss	70dB
Transmit Model	40W
Traffic model	Full buffer
Schedule type	Proportional fair

**Figure 3.**Forecast for the average cell SE over years

The simulation parameters are shown in Table 2. The simulation scenarios for technical deployment such as the ratio of transmission mode and antenna configuration are followed to [8]. Figure 3 shows the prediction of spectral efficiency. In the case of ISD 200m, the spectral efficiency is reduced by average 15.3% compared with the case of ISD 500m.

**Figure 4.** The growth of the number of Sample Cells**Figure 5.** 4G traffic volume and system capacity in VSR

The spectral efficiency for ISD 200m is 1.24 in 2017, 1.45 in 2018, and 1.59 in 2019 while that for ISD 500m is 1.78 in 2017, 1.88 in 2018, and 1.96 in 2019, respectively. We used the value for ISD 200m to estimate the VSR capacity.

3) Spectrum reuse factor: The growth of the number of sample cells in VSR is shown in Figure 4. We also used real statistical data from Mar. 2017 to Mar. 2019 in Seoul, Korea. As VSR consists of sample cells with upper 10% of RBs utilization in Seoul, the number of sample cell is one tenth total cells in Seoul. The number of 4G cell in Seoul has increased by average 39.8% from March 2017 to March 2019.

4) System Capacity

Using the derived spectrum bandwidth, spectral efficiency, spectrum reuse factor, we evaluated the system capacity for each frequency band and combined them. Figure 5. shows the estimated system capacity and real traffic volume in VSR. The margin of real traffic(demand) and system capacity(supply) is average 28.5%. The capacity margin of each quarter in VSR is shown in Table 3.

Table 3. The margin of capacity in VSR

Quarter	Margin
'17.03	31.2%
'17.06	24.8%
'17.09	25.4%
'17.12	26.5%
'18.03	36.0%
'18.03	28.2%
'18.06	26.2%
'18.09	26.8%
'18.12	31.9%
'19.03	31.2%

IV.CONCLUSION

Mobile traffic has continuously increased due to spread of smartphone and video services in cellular networks, and the

network operator must expand their system capacity according to the growth. In this paper, we propose virtual sample region concept to evaluate the balance between demand and supply of traffic. To evaluate spectral efficiency SLS for 4G network is performed using modified Vienna LTE-A simulator, and finally we evaluate system capacity to compare measured traffic volume in VSR using real measured data in Seoul, Korea. As 5G services became commercially available in Korea in April 2019, the demand and supply of 5G traffic can also be estimated by VSR concept.

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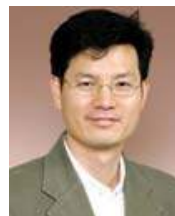
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