
Traffic Offload Guideline and Required Year of the 50% Traffic Offloading

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Abstract

Smart Phone and tablet terminals are widely accepted into mobile society and support wireless cloud service effectively. Terminals generally adopt flat rate tariff and the traffic is increasing rapidly. To solve this problem, new technology developments and new spectrum resource allocations and assignments are intensively executed. However in quite near future, traffic will overcome this action. This paper proposes the traffic offloading to microcells and give numerical guideline of offloading ratio that minimize the total radio base station cost under the existing spectrum resource allotment. First, offload guideline is derived based on the Japanese congested area case study in Shibuya ward, and this guideline is translated and generalized to global circumstances. Using the guideline, the required offloading year is calculated for the high population cities or wards in the world. From the results of the analyses, it is shown that the traffic offloading to microcell is necessary in near future. This result is valuable and inevitable to minimize increasing spectrum allotment to the existing mobile service. To monitor the offload ratio, it is better to analyze social bigdata and the carrier's bigdata. In the final part, example of Draft Question for ITU-R is proposed.

Keywords: Traffic offloading to microcell, Offload guideline, Radio base station cost minimization, 3GPP TS LIPA SIPTO.

1 Introduction

Wireless broadband access is rapidly penetrating into mobile communication service and terminals, such as smart phone, tablet PC, wireless cloud and so on. Rapid growth of wireless broadband access generates very heavy traffic on the mobile networks. It is well known that the bottleneck for heavy traffic is comes from radio spectrum limitation. To handle heavy traffic, new technology and new radio frequency band allocation have been developed intensively. They were powerful motivation of the global research and development on wireless technologies, including signal processing and control.

However the traffic growth of smart phone has different nature from the existing mobile service, such as voice and mail service. They are similar to fixed broadband service, in that the flat rate tariff is introduced to enhance user utility for various cloud services. For the user utility and mobile carrier benefit, new fruitful applications should be supported by wireless cloud, as same as in fixed networks. Such a increasing wireless broadband traffic will overcome existing technology development and radio spectrum allocation in near future.

Proper solution to solve this bottleneck, it is requested to implement new microcell radio base station (RBS) to the congested area. This is called as the traffic offloading to microcell. [1–3] 3GPP published TS 23.829, TS 23.859 and TS 22.220, in that H(e)NB, Local IP Access (LIPA) and Selected IP Traffic Offload (SIPTO) are described. H(e)NB includes Home Node B (HNB) and Home e-Node B (HeNB), they are working on 3GPP frequency bands and set in the home or the office building. SIPTO is a method where portions of the IP traffic on a H(e)NB access or cellular network is offloaded to a local network, in order to reduce the traffic load on the existing 3GPP networks, called as core system or macrocell system. In the TS 23.402, the non-3GPP access, such as trusted/non-trusted wireless LAN (WLAN) access, is also defined. In the following part of this document, the SIPTO using H(e)NB and the trusted/non-trusted WLAN access are called as femtocell system and WLAN access system, respectively. Also it is defined that microcell system includes femtocell and WLAN access. Existing large area system operating in 3GPP band is called as macrocell.

Technological issues have already been prepared as is mentioned, however the traffic offloading to femtocell is not widely implemented, by the reasons of the spectrum coordination between macrocell and femtocell, the difficulty of air interface update on femtocell RBS and the difficulty on RBS management and maintenance issue. Considering the existing WLAN, one of promising

traffic offloading may be trusted/non-trusted WLAN access. Any way, it is necessary to enhance and promote the offloading to microcell including femtocell and WLAN, by setting up the offload guideline to congested cities. Obtained result suggests that the congested city in the world requires early offloading in the near future.

In this paper, traffic offloading to microcell is analyzed, and the cost minimized offloading guideline is proposed. Analyses are done under the condition of total RBS cost minimization and existing spectrum resource is fixed and limited. The optimum offload guideline is calculated by using real congested city parameter in Shibuya-ward, Tokyo Metropolitan area, Japan. Obtained results are generalized and applied to the congested cities and wards in the world.

The guideline calculates required 50%-traffic offloading year for various cities and wards.

Definition of required 50%-offloading year means that the communication quality of service (QoS), such as the latency time and the throughput in the data communication, is seriously degraded, if the offloading is not put into force. In this analyses, all the data is assumed to be the Packet Switched (PS) based data traffic, and the throughput decrease and the latency time increase in the PS mean that the voice call blocking rate increases in the circuit switched (CS) system, when PS and CS co-share bandwidth of trunk line. So if traffic offloading to microcell is not taken after the required 50%-traffic offloading year, the communication QoS, such as latency time and call blocking, seriously decreases not only in data communications but also in voice communications.

If there is no traffic offloading guideline, mobile carriers select another business tactics. To solve the bottleneck in easygoing manner, it may be considered to introduce the non flat-rate tariff or the limited monthly quota. This strategy is not good selection for wireless cloud era, from the viewpoint of the competition among mobile carriers and also social utility. Another solution may be traffic control and/or shaping. The concept of network neutrality already set up in fixed networks, and it requires fairness, reasonable and transparent control. Non flat-rate tariff implementation to users may not be easy issue under the competition among several mobile carriers.

If the new macrocell RBSs are additionally build in the congested area to maintain QoS, the RBS invest cost without offloading becomes higher comparing with the traffic offloading to microcell, and results in the lose competition power among carriers.

Chapter 2 mentions current and forecast of estimated monthly traffic per capitain Japan. Chapter 3 describes the structure of traffic offloading.

Chapter 4 describes analysis model and principle to minimize total cost of mobile base stations. In this chapter, Clark's city model and cost ratio of macrocell and microcell base station is introduced to generalize the analysis. Chapter 5 shows the result of Shibuya ward, and the generalized value of traffic offload guideline is proposed. Chapter 6 derives the required 50%-traffic offloading year, based on the proposed generalized guideline. And some examples of the required offloading year are shown for various high population density cities and wards in the world, and it is shown that the time limit for offload is critical and very near in the congested cities.

2 Traffic Growth of Mobile Service

Japanese mobile traffic is monitored and prospected in the various organizations [4–6]. Figure 1 shows the monthly data size per capita (GB/month).

The Ministry of Internal Affairs and Communications Japan (MIC), summarized the existing network traffic report in 2004. In those days, compact HTML based on the i-Mode service and text mail were dominant, and the

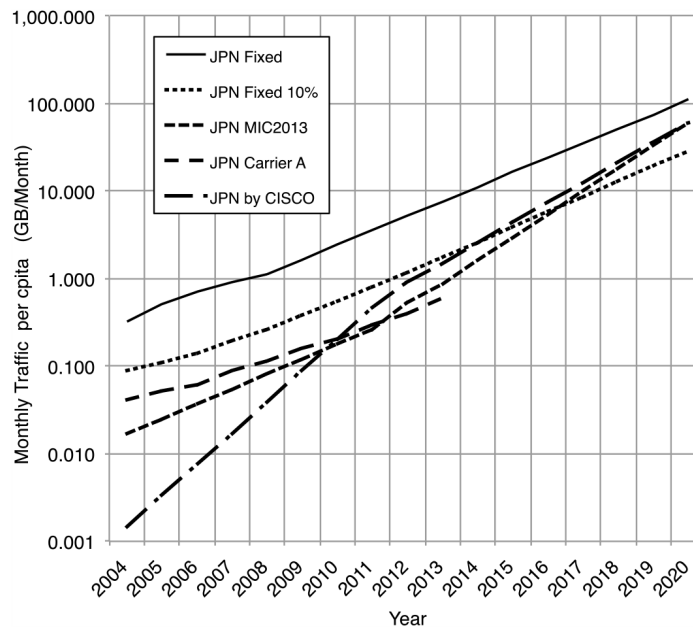


Figure 1 Japanese mobile traffic status and prospect

traffic is smaller comparing with the today's traffic. In 2013, the real traffic is monitored and estimated by MIC. Also two mobile carriers in Japan prospected from their observed traffic in 2007. Those are shown in the figure, and lies little bit smaller than 10% of the fixed internet services. Traffic of fixed broadband service increases annual rate of 46%. From the estimations, target traffic of 3years later from now, i.e. 2017, reaches 10GBytes/month. Traffic estimated by Cisco is also illustrated in the figure. The annual growth rate (ARG) is as same as that measured by Japanese organizations. As shown in the figure, traffic growth is very rapid and the monthly traffic volume reaches to near volume of the fixed internet services. This is the motivation of the guideline setup.

3 Traffic Offload

Conceptual schema of traffic offload is shown in Figure 2. Figure 2(a) shows existing macrocell system without traffic offload, and all users utilize same macrocell mobile base station. Figure 2 (b) shows traffic offload to microcell system. In high population and/or high traffic area, microcell base stations, for example trusted/untrusted WLAN access is implemented, and traffic is offloaded to microcell mobile station. Usually, microcell base station is connected through fixed broadband networks and vertical handover between microcell and macrocell mobile networks are essential. Microcell base stations are implemented in high traffic area in highpriority. As the result of the priority, the traffic offload ratio is larger than microcell area ratio, as is shown in Figure 4.

4 Analysis Model

Evaluation parameter for offload guideline is the total RBS cost minimization under the limitation of existing radio spectrum. Outline of the model and the used parameters are summarized in Table 3. Detailed issue of the analysis model is shown in Section 4.1 through 4.4.

4.1 City and Population Model

Shibuya ward, Tokyo metropolitan in Japan is selected as a typical high traffic area. The obtained result is translated and generalized to the other global area shown in the chapter 5. Profile of Shibuya ward is shown in Table 1. Offered communication traffic is estimated from daytime population, because the peak traffic at go home hour is closely relating with a day time population.

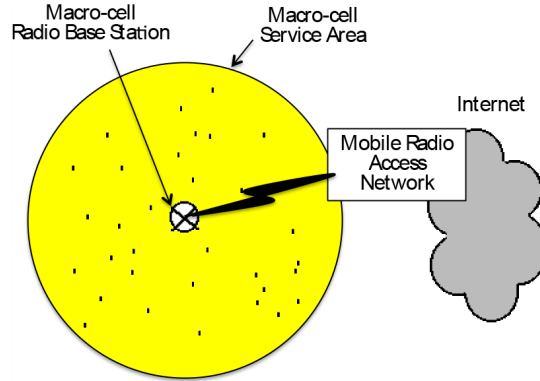


Figure 2 (a) Existing macrocell system

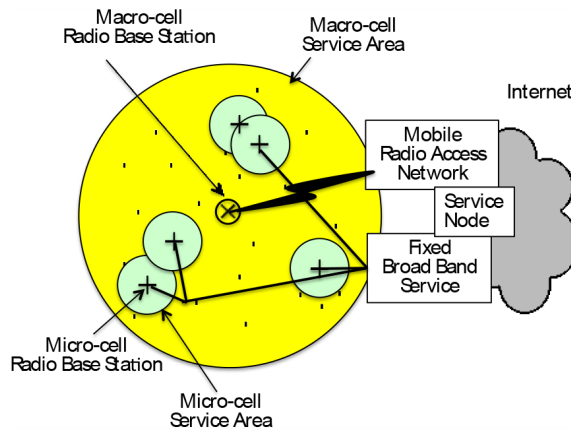


Figure 2 (b) Traffic offloading to microcell

Real population distribution of Shibuya is like Figure 3(a). Some shopping mall and vicinity of railway stations show traffic peaks at several points and peak concentration ratios are different among them. This is generalized to equivalent Clark's city model [7] shown in Figure 3(b). This city model has circular area that has same space, same population of Shibuya ward and modified equivalent population concentration ratio at the city center.

Using Clark's Model, population density $f(r)$ is exponential and given by,

$$f(r) = \eta e^{-dr} \quad (1)$$

Table 1 Profile of shibuya ward in Tokyo metropolitan, Japan

Daytime Population N_d [person]	559,000
Area S_{area} [m ²]	15,110,000
Mobile Subscription rate R_m [%] (National Mean Value)	78
Equivalent City Radius of Shibuya (Circular Model) R [m]	2,193
Specified Carrier Share R_d [%] (Tokyo area)	53.7
Number of Users P_{area}	234,157
Population Concentration Ratio (Clark City Model) β	3
Time Concentration Ratio β_t	3
City parameter η [person/m ²]	0.1395
City parameter d	1.8477×10^{-3}

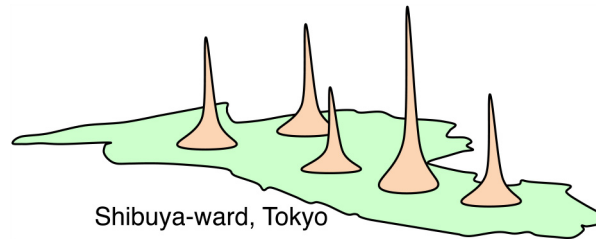


Figure 3 (a) Real population distribution of shibuya ward, Tokyo metropolitan, Japan

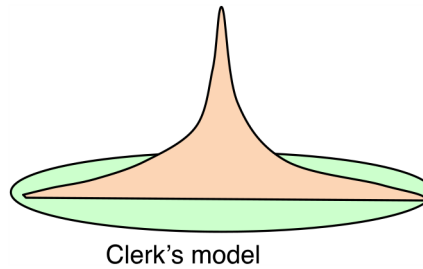


Figure 3 (b) Equivalent population model of Clark model for calculation

where, r denotes distance from city center, and η , d are parameters, those are calculated as follow.

If the total daytime population N_d exists in the all city area S_{area} , and city radius is $R = \sqrt{S_{area}/\pi}$, and introduce the population concentration ratio β defined by the ratio of maximum population density at the city center and

average population density, then peak population density η at the city center is shown

$$\eta = \beta \frac{N_d}{S_{area}} = \beta \frac{N_d}{\pi R^2} \quad (2)$$

Population N_d exists in the city area S_{area} , then

$$N_d = \int_S f dS = \int_0^R 2\pi r f(r) dr = \frac{2\pi\eta}{d^2} (1 - (1 + dR) e^{-dR}) \quad (3)$$

Substitute (3) into (2) then,

$$(dR)^2 + 2\beta (1 + dR) e^{-dR} - 2\beta = 0 \quad (4)$$

From the equation, parameter d is determined by using population concentration ratio β and city radius $r = \sqrt{S/\pi}$.

Supposing that the WLAN access point is installed first priority at the highest population area, WLAN available population ratio δ , that is defined by the ratio of WLAN available population and total population, is

$$\delta = \frac{\int_0^{r_{BS}} 2\pi r f(r) dr}{\int_0^R 2\pi r f(r) dr} \quad (5)$$

where, r_{BS} denotes equivalent radius of WLAN equipped circle area. If the WLAN installed area ratio α is defined by the ratio of WLAN installed area and total city area, and then

$$\alpha = \frac{\pi r_{BS}^2}{\pi R^2} \quad (6)$$

Using Equation (5) and (6), relation between δ and α is given as follow.

$$\delta(\alpha) = \frac{1 - (1 + dR\sqrt{\alpha}) \exp(-dR\sqrt{\alpha})}{1 - (1 + dR) \exp(-dR)} \quad (7)$$

Figure 4 shows the WLAN access available population ratio $\delta(\alpha)$, for Shibuya ward, where $S = 15,110,000 [m^2]$, and population concentration ratio $\beta = 1, 3, 6, 9$.

As is seen in the figure, in case of population concentration ratio of $\beta = 3$, 30% of population, i.e. traffic, can be offloaded, by installing WLAN into the 20% of total area. In case of more population concentrated case of $\beta = 9$, the 60% of traffic can be offloaded to WLAN by installing it into only 20% of total area.

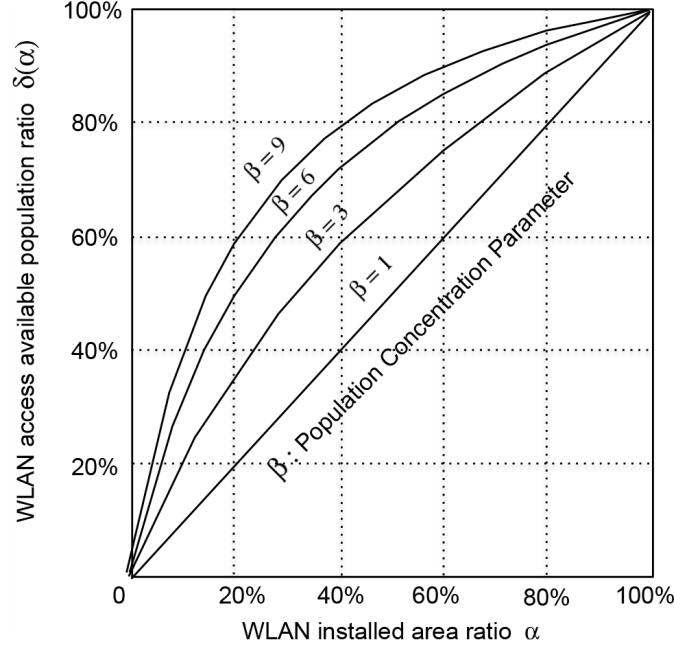


Figure 4 Relation between WLAN installed area ratio α [%] and WLAN available population ratio δ [%]

4.2 Radio Base Station Model

Radio base station model and specifications are summarized in Table 2. Macrocell system utilizes LTE and WLAN utilizes IEEE802.11n operated in 5GHz to avoid interference from existing 2.4GHz users. Effective throughput is estimated by 20% of maximum throughput.

4.3 Traffic Model and Latency Time

Offered traffic of macrocell and microcell, D_{macro} , and D_{micro} , respectively, are

$$D_{macro} = (1 - \delta(\alpha)) \frac{A P_{area}}{n_{macro}} \quad (8)$$

$$D_{micro} = \delta(\alpha) \frac{A P_{area}}{n_{micro}} \quad (9)$$

Table 2 Radio base station model for analysis

	Macro-cell	Micro-cell
System Name	LTE	IEEE802.11n
Bandwidth [MHz]	10*	20***
Number of RF Carriers [ch]	2**	3
Number of Sectors	3	1
MIMO	2x2	3x3
Maximum Capacity [Mbps]	86	156
Effective Throughput [%]		20
[Mbps]	17.5	31
Effective System Capacity [Mbps]	35	93
Cell Radius [m]	500	20
Area Size [m ²]	785,398	1,256

*: one of pair band for frequency division duplex (FDD).

** : assigned channels to the one operator, i.e. equivalent to total.

***: time division duplex (TDD) bandwidth.

where, A , P_{area} , n_{macro} and n_{micro} , are the traffic from one user, the number of total users in the city for a specific mobile carrier, the number of macrocell RBS and the number of microcell RBS, respectively.

Required throughput of each macrocell and microcell RBS, ρ_{macro} and ρ_{micro} are

$$\rho_{macro} = (1 - \delta(\alpha)) \frac{AP_{area}}{n_{macro}T_{macro}} \quad (10)$$

$$\rho_{micro} = \delta(\alpha) \frac{AP_{area}}{n_{micro}T_{micro}}, \quad (11)$$

where T_{macro} and T_{micro} is the effective system capacity of each macro and microcell RBS, respectively.

To analyze the internet traffic, it may be better to use fractal or log-normal distribution not Poisson process, however, in this analysis, the widely used M/M/1/FCFS (Fast Come First Served) packet switched (PS) system is assumed, for the easiness of calculation and first order approximation. In this analyses, all the data is assumed to be the PS based traffic, and throughput decrease and latency time increase in PS means equivalent for the voice call blocking in circuit switched (CS) system, when PS and CS co-share bandwidth of trunk line.

Queue length $E[n_t]$ is

$$E[n_t] = \frac{\rho}{1 - \rho}, \quad (12)$$

where ρ is average throughput of the system. From Littele's Law,

$$E[n_t] = \lambda E[t], \quad (13)$$

where $E[t]$ and λ denote the mean latency time and the mean packet arrival, respectively. The mean packet size and the maximum capacity are denoted by s and T , then the mean through put ρ will be given by

$$\rho = \frac{\lambda s}{T} \quad (14)$$

Then the mean latency time $E[t]$ is given as follow.

$$E[t] = \frac{s}{T(1 - \rho)} \quad (15)$$

For the web browsing, packet size distribution is known as log-normal distribution, and observed mean value is 11.18, and variance is 2.24 [9]. Mean data size s is $s = exp(11.18 + (2.24)^2/2) = 880$ [kB].

Using Equation (10), (11) and (15), macrocell and microcell latency time, $E[t]_{macro}$ and $E[t]_{micro}$ are as follows,

$$E[t]_{macro} = \frac{s}{T_{macro} - (1 - \delta(\alpha)) \frac{AP_{area}}{n_{macro}}} \quad (16)$$

$$E[t]_{micro} = \frac{s}{T_{micro} - \delta(\alpha) \frac{AP_{area}}{n_{micro}}} \quad (17)$$

4.4 User Utility and Required Latency Time

Relation between user utility $U(t)$ and latency time t is measured and show exponential relation, and given by

$$U(t) = g e^{-ht} \quad (18)$$

where g and h are parameters, and in case of fore ground picture browsing, following values are observed by using mean opinion score (MOS) experiment, based on ITU-R BT500-10 double-stimulus impairment scale (DSIS). User utility value U , i.e. MOS value, has in 0 (not allowable) to unity (no degradation), and allowable limit is normally set 0.6 (degraded but allowable). Figure 5 shows experimental results for various download case of Web Foreground (Web-F), FTP-Foreground (FTP-F) and FTP-Background (FTP-B). Web-F is normal user style for smart phone terminal, and most intolerant case. In this case, user utility U is shown as follow [8],

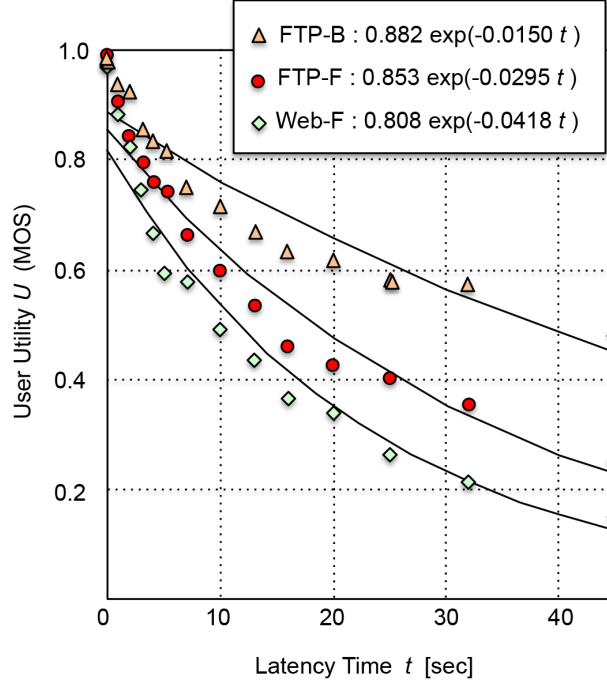


Figure 5 User utility and latency time

$$U(t) = 0.808 \exp(-0.0418 t) \quad (19)$$

i.e. $g = 0.808$ and $h = 0.0418$.

If we set required MOS value $u = 0.6$, then the objective mean latency time $E[t]$ is determined by the following Equation.

$$E[t] = -\frac{1}{h} \ln(u/g) = 6.9 \text{ [sec]} \quad (20)$$

From the Equation (16) and (20),

$$E[t]_{macro} = \frac{s}{T_{macro} - (1 - \delta(\alpha)) \frac{AP_{area}}{n_{macro}}} \leq -\frac{1}{h} \ln(u/g) \quad (21)$$

Then necessary base stations n_{macro} is given as follow.

$$n_{macro} \geq \frac{(1 - \delta(\alpha)) AP_{area}}{T_{macro} + s h / \ln(u/g)} \quad (22)$$

Also the necessary base stations n_{micro} is given as follow.

$$n_{micro} \geq \frac{\delta(\alpha) AP_{area}}{T_{micro} + s h / \ln(u/g)} \quad (23)$$

WLAN installed area ratio is determined by α , so the following condition should be satisfied.

$$\alpha \leq \frac{n_{micro} S_{micro}}{S_{area}}, \quad (24)$$

where S_{micro} denotes the area of each microcell.

4.5 Total Cost Minimization by Traffic Offloading to WLAN Access

Total cost minimizing method and parameters are summarized in Table 3.

Mobile base station selection strategy and cost minimization are as follows.

1. Daytime population density is estimated from the Clark's city model. User density of the specific mobile carrier is calculated using their share.
2. Area traffic is calculated from the average user traffic per capita and the user density. Busy hour traffic concentration ratio of $\beta_t = 3$ is considered in this stage, which is shown in Table 1.
3. Required latency time, i.e. 6.9 [sec], which is derived from the utility function shown in Equation (20), decides the required throughput and number of base stations for macrocell and microcell, i.e. Equation (22) and Equation (23), respectively.
4. Minimize the sum of base station costs, and then decide offload ratio.

To minimize total RBS cost, cost ratio of macrocell RBS and micocell RBS is important parameter. RBS cost ratio C is defined by

$$C = C_{macro} / C_{micro} \quad (25)$$

where, C_{macro} and C_{micro} are the cost of each macrocell RBS and the cost of each microcell RBS, respectively.

Total RBS cost, $Cost$ is given as follow,

$$\begin{aligned} Cost &= C_{macro} \times n_{macro} + C_{micro} \times n_{micro} \\ &= C_{macro} \frac{(1 - \delta(\alpha)) AP_{area}}{T_{macro} + s h / \ln(u/g)} + C_{micro} \frac{S_{area}}{S_{micro}} \alpha \end{aligned} \quad (26)$$

Table 3 Mobile base station selection model

City Model and Population Density	<p>Metroplotan Area (Shibuya ward, Tokyo, Japan)</p> <ul style="list-style-type: none"> • Area Model: Clark Circular City Modle, • Area: Equivalent to Shibuya ward, Radius 2.193 km, Area size 15.1 km² • Daytime Population: 559,000 persons • Population Density: Population decreasing exponentially toward city fringe City center concentration factor = 3
Traffic Model	<ul style="list-style-type: none"> • Data Traffic Queuing System (M/M/1 /FCFS) • Poisson Distributed Traffic, Mean traffic per user A is viable parameter • Busy hour traffic ratio = 3
User Utility and Required Latency Time	<ul style="list-style-type: none"> • User utility function (Handa:2007): Web foreground download $U(t) = 0.808 \exp(-0.0418t)$ ITU-R BT. 500-10 (DSIS:Double-stimulus impairment scale) • Latency time: Less than 7 seconds, in that user utility U more than 0.6.
Radio Base Station Implementation Methodology (Offload Guideline)	<p>Mobile Base Station Implementation Methodology</p> <ul style="list-style-type: none"> • No spectrum allocation of new RF carriers and new bands • Implement Traffic Offload System to microcell base station • Number of Microcell and Macrocell Basestations <ul style="list-style-type: none"> • Cost minimum implementation of macro and micro cell BS • Fullfill user utility of more than 0.6 • BS implementation cost ratio C is variable $C = \text{Macrocell BS Cost} / \text{Microcell BS Cost}$
Mobile Service Operator's Profile and Base Station Equipment	<p>Market share of one operator: 53.7% (Tokyo vicinity) Mobie Subscription ratio: 78% (Avarage of Japan) Radio Equipment:</p> <ul style="list-style-type: none"> • Macrocell: LTE 10MHz, 2 pair bands, MIMO 2x2 Maximum speed: 85.7Mbps/band Effective throughput: 20% Area size (radius): 500 m • Microcell:IEEE 802.11 n, 20MHz, 4 bands Maximum speed: 150 Mbps/band Effective throughput: 20% Area size (radius): 20 m

Then optimum WLAN installed area ratio α is derived as Equation (27),

$$\alpha = \begin{cases} 0 \\ \frac{\pi}{d^2 S_{area}} \left(\ln \left(\frac{\eta C S_{micro}}{T_{macro} + sh / \ln(u/g)} \right) \right)^2 \\ 1 \end{cases} \quad \begin{aligned} & : A < \frac{T_{macro} + sh / \ln(u/g)}{\eta C S_{micro}} \\ & : \frac{T_{macro} + sh / \ln(u/g)}{\eta C S_{micro}} < A < \frac{T_{macro} + sh / \ln(u/g)}{\eta C S_{micro} e^{-d\sqrt{S_{area}/\pi}}} \\ & : A > \frac{T_{macro} + sh / \ln(u/g)}{\eta C S_{micro} e^{-d\sqrt{S_{area}/\pi}}} \end{aligned} \quad (27)$$

5 Results and Traffic Offload Guideline

5.1 Required Number of Base Stations

Numerical calculation is executed based on the model and process in chapter 4. Results are shown in Figure 6.

Figure 6(a) and (b) show number of required macrocell and microcell base stations n_{macro} , n_{micro} vs traffic per users B_u . In the figures, each base station cost ratio C defined by Equation (25) is changed from 5 to 100. As is seen in the figures, traffic offload is inevitable around user traffic of 1GB to 10GB/month.

For the general use of calculated results in any city, the traffic per user T_u [bps/user] is translated to the monthly data size per user B_u [byte/month/user], the traffic per unit area T_a [bps/m²] and the monthly data size per unit area B_a [byte/month/m²]. Following equations are translation equations.

$$B_u = T_u \times 60sec \times 60min \times 24hour \times 30days / 8bit = 3.24 \times 10^5 T_u \quad (28)$$

$$T_a = T_u N_d R_m \frac{R_d}{S_{area}} = 0.016 T_u = 4.94 \times 10^{-8} B_u \quad (29)$$

$$\begin{aligned} B_a &= B_u N_d R_m \frac{R_d}{S_{area}} = 0.016 B_u = 0.016 \times 3.24 \times 10^5 T_u \\ &= 5184 T_u = 3.24 T_a \end{aligned} \quad (30)$$

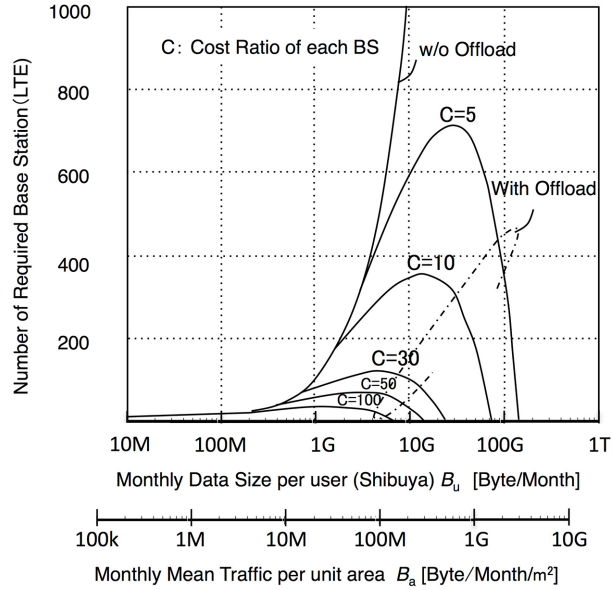


Figure 6 (a) Number of required mobile base stations for macrocell

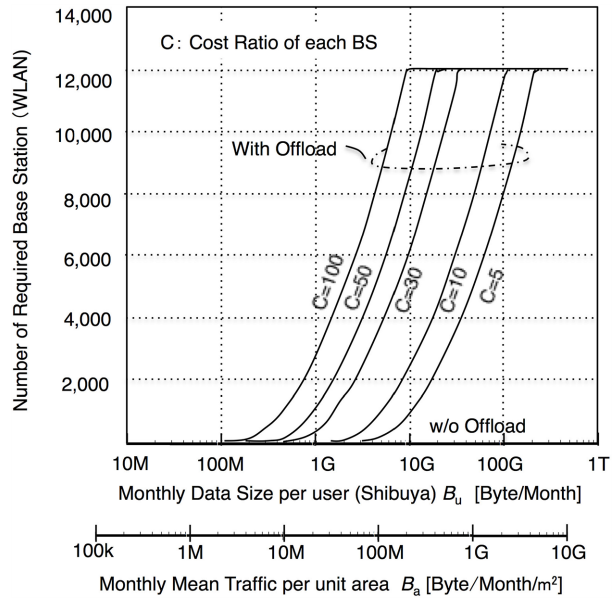


Figure 6 (b) Number of required mobile base stations for microcell

where N_d , R_m , R_d and S_{area} are daytime population, subscription ratio of mobile service, share of a specific mobile carrier and area of Shibuya ward, respectively, and $N_d = 559,000$, $R_m = 78\%$, $R_d = 53.7\%$, $S_{area} = 15,110,000$ m², as shown in Table 1.

5.2 Traffic Offload Ratio in Shibuya-Ward and Generalized Guideline for Various City

The required traffic offload ratio is calculated in Shibuya-ward, and the results is shown in Figure 7 according with the monthly data size per user B_u . As is seen in Figure 1, traffic will reach around 10GB/user/month in 5 years. In case of macrocell RBS cost is high, i.e. $C=100$, more than 80% of traffic should be offloaded to microcell base station, in the congested area. Even if the macrocell RBS cost becomes lower, i.e. $C=5$, several % of traffic should be offloaded in the high population area.

From this results, the required 50%-traffic offload year in Shibuya-ward will be calculated 2014 incase of $C=100$, and 2018 in case of $C=5$. Relation between the offload ratio δ [%] and the microcell installed area ratio α [%] is

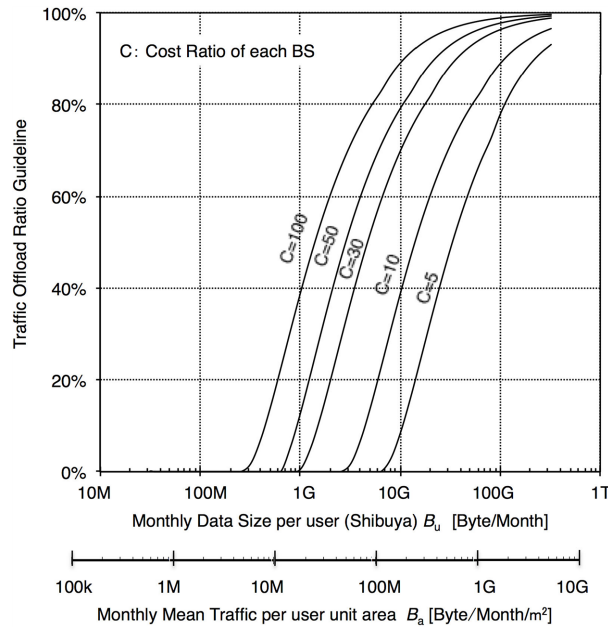


Figure 7 Traffic offload ratio guideline

shown in Figure 4, and from this figure, 50% offload means the microcell area ratio is 30% in case of the population concentration ratio $\beta = 3$.

If the traffic offload ratio, calculated in Shibuya-ward, is translated to the monthly data size per unit area B_a , the results obtained in Shibuya-ward is generally applicable to the other city in the world. In Figure 7, the monthly data size per unit area B_a is shown simultaneously. To follow the guideline, it is important that the parameter Monthly traffic per unit area B_a [byte/month/m²] is easy to measure and transparent. The parameter B_a [byte/month/m²] and traffic offload ratio may be measured by the mobile service operators already, however, it is not transparent to us, and all the congested cities in the world can not open such a data. Then, it is required to estimate the parameter by using the social and open bigdata. Next Section 7 shows the examples of the estimated results.

6 Required 50%-Traffic Offloading Year of Various Cities in the World

In this section, it is calculated that the several examples of the required 50%-Traffic Offloading year of various cities in the world. Required offloading year is briefly mentioned in the previous section. In this section, details of the calculation methods are defined. The calculation method is the following steps.

Monthly data traffic in n years after from 2012 per one user $B_{u,n}$ is calculated by the following equation.

$$B_{u,n} = B_{u,2012}(1 + AGR_t)^n \quad (31)$$

where $B_{u,2012}$, and AGR_t are monthly data traffic in year 2012 per capita and annual growth rate in user traffic, respectively. Monthly mean data traffic per unit area in n years after from 2012, that is denoted by $B_{a,n}$ is calculated by the following equation.

$$B_{a,n} = B_{u,2012}(1 + AGR_t)^n P_{ud,2012}(1 + AGR_u)^n \quad (32)$$

where $P_{ud,2012}$, and AGR_u are mean user density in year 2012 and annual growth rate in number of users, respectively. In this paper, mean user density $P_{ud,2012}$, is assumed and calculated from the population density P_d . For the easiness of estimation, it is estimated by $P_{ud,2012} = P_d$ in case of $AGR_u < 1.5\%$ and $P_{ud,2012} = 0.8 \times P_d$ in case of $AGR_u > 1.5\%$.

Table 4 Guideline value of monthly traffic per unit area $B_a|_{x\%}$

Offload Ratio x [%]	Guideline of Monthly x%-Traffic Offload Per Unit Area, $B_a _{x\%}$ [MB/ Month/m ²]			
	C=100	C=50	C=10	C=5
10%	5	14	64	160
50%	24	45	208	480
90%	176	320	1,920	3,360

C : Cost ratio between Macrocell BS and Microcell BS

From Figure 7, we can obtain the guideline value of monthly traffic per unit area $B_a|_{x\%}$ [MB/month/m²]. Table 4 shows this value.

Using this guideline $B_a|_{x\%}$, required year n for offload is obtained from the following equation.

$$n = \log((B_a|_{x\%} \times R_b) / (B_{u,2012} \times P_d)) / \log((1 + AGR_t)(1 + AGR_u)) \quad (33)$$

where, R_b denotes the bandwidth allocation ratio for various countries. There are wide variety of band assignments depend on the country, however 60MHz pair bands or 120MHz TDD bands are assumed in this analyses for the calculation easiness. Population density P_d is referred from Wikipedia [10]. The monthly data traffic in year 2012 per capita $B_{u,2012}$, the annual growth rate in user traffic AGR_t , and the annual growth rate in number of users AGR_u are referred from Cisco [6]. Data is summarized in Table 5.

Calculated results using Equation (33) are shown in Figure 8 (a) and (b). In the figures, base station cost ratio C is selected as variable parameter.

Figure 8 (a) shows the required 50%-traffic offloading year at the RBS cost ratio $C = 100$, and this shows that almost all cities of the high population density should be traffic offloaded by the end of 2014 or 2015. Figure 8(b) shows the required 50%-traffic offloading year at the RBS cost ratio $C = 5$, and this shows that almost all cities in high population density should be traffic offloaded by the end of 2016, even if the RBS cost of macrocell is reduced and increase the number of macrocell RBS.

7 Draft Proposal of Question

From the results of this research, Draft proposal of Question is proposed, as follow.

DRAFT NEW PROPOSAL OF QUESTION ITU-R XXX
 Guideline of traffic offload ratio for mobile service
 (2012-201x)
 The ITU Radio Communication Assembly, considering

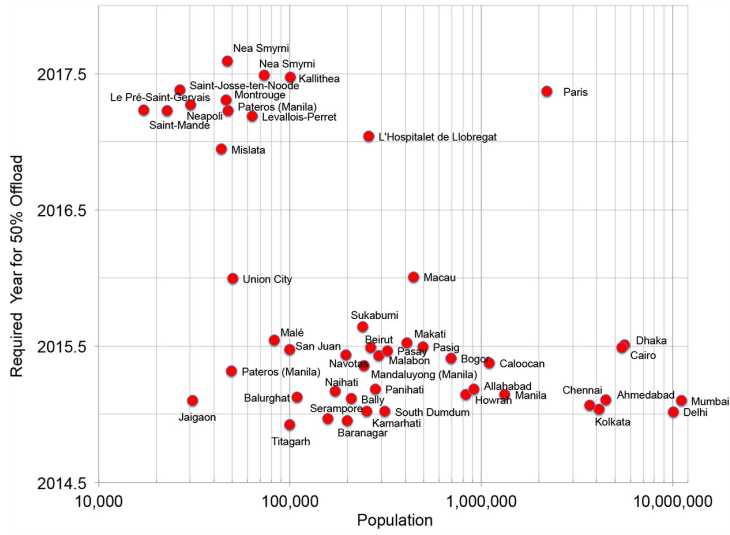


Figure 8 (a) Required year for 50% traffic offload (C=100)

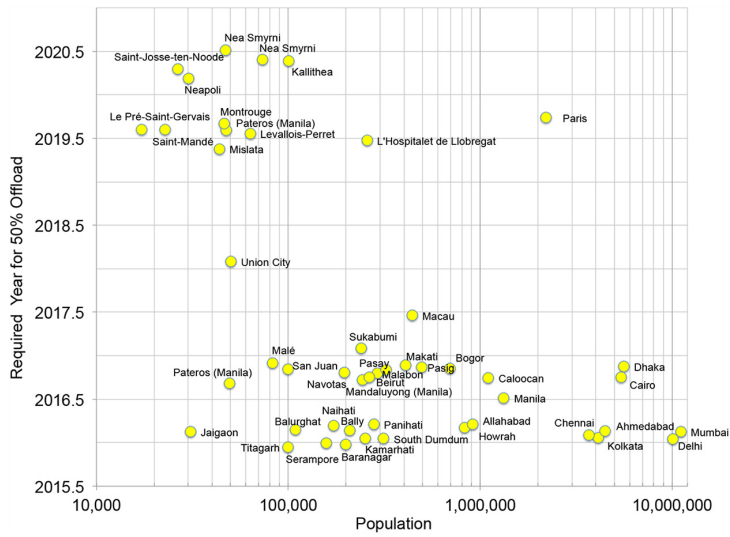


Figure 8 (b) Required year for 50% traffic offload (C=5)

Table 5 Population density and other parameters of various congested cities

City or Ward Name	Population	Estimated Subscribers	Area (km ²)	Population Density (/km ²)	Country	Traffic per		
						User at 2012 Bu (MB)	AGR on Traffic AGRt (%)	AGR on Users AGRn (%)
Mamila	1,660,714	1,328,571	38.55	43,079	Philippines	108	71	4.2
Bogor	866,034	692,827	21.56	40,169	Indonesia	93	63	3.9
Titagarh	124,213	99,370	3.24	38,337	India	23	108	7.9
Baranagar	248,466	198,773	7.12	35,220	India	23	108	7.9
Serarpore	197,857	158,286	5.88	33,649	India	23	108	7.9
Pateros	61,940	49,552	2.1	29,495	Philippines	108	71	4.2
Delhi	12,565,901	10,052,721	431	29,155	India	23	108	7.9
South Dumdum	392,444	313,955	13.54	28,984	India	23	108	7.9
Kamarhati	314,507	251,606	10.96	28,696	India	23	108	7.9
Kolkata	5,138,208	4,110,566	185	27,774	India	23	108	7.9
Ahmedabad	5,570,585	4,456,468	464	22,473	India	23	108	7.9
Mandaluyong	305,576	244,461	11.26	27,138	Philippines	108	71	4.2
Levallois-Perret	63,225	63,225	2.42	26,126	France	244	47	1.4
Neapoli	30,279	30,279	1.17	25,879	Greece	771	39	1
Caloocan	1,378,856	1,103,085	53.34	25,850	Philippines	108	71	4.2
Chennai	4,616,639	3,693,311	181.04	25,501	India	23	108	7.9
Vincennes	47,372	47,372	1.9	24,802	France	244	47	1.4
Sukabumi	300,694	240,555	12.15	24,748	Indonesia	93	63	3.9
Saint- Mandé	22,737	22,737	0.9	24,714	France	244	47	1.4

(continued)

Table 5 Continued

City or Ward Name	Population	Estimated Subscribers	Area (km ²)	Population Density (/km ²)	Country	Traffic per		
						User at 2012 Bu (MB)	AGR on Traffic AGRt (%)	AGR on Users AGRu (%)
Le Pré- Saint-Gervais	17,244	17,244	0.7	24,635	France	244	47	1.4
Saint- Josse-ten- Noode	26,488	26,488	1.14	23,235	Belgium	771	39	1
Malabon	363,681	290,945	15.76	23,076	Philippines	108	71	4.2
Mumbai	13,830,884	11,064,707	603	22,937	India	23	108	7.9
Jaigaon	38,689	30,951	1.69	22,893	India	23	108	7.9
Navotas	245,344	196,275	10.77	22,780	Philippines	108	71	4.2
Mont rouge	46,500	46,500	2.1	22,464	France	244	47	1.4
Banupur	11,647	9,318	0.52	22,398	India	23	108	7.9
Guttenburg	11,176	8,941	0.628	22,052	USA	763	55	1.7
Bally	260,906	208,725	11.81	22,092	India	23	108	7.9
Balughat	135,737	108,590	6.37	21,309	India	23	108	7.9
Mislata	43,756	43,756	2.06	21,241	Spain	483	42	1.4
Pasay	403,064	322,451	19	21,214	Philippines	108	71	4.2
Kallithea	100,050	100,050	4.75	21,068	Greece	771	39	1
Paris	2,193,031	2,193,031	105.4	20,741	France	244	47	1.4
San Juan	124,187	99,350	5.94	20,907	Philippines	108	71	4.2

Nea Smyrni	73,090	73,090	3.52	20,740	Greece	771	39	1
Pasig	617,301	493,841	31	19,913	Philippines	108	71	4.2
Howrah	1,034,372	827,498	51.74	19,992	India	23	108	7.9
Dhaka	7,000,940	5,600,752	360	19,447	Bangladesh	108	71	4.2
Union City	62,715	50,172	3.29	19,066	United States	763	55	1.7
L'Hospitalet de Llobregat	257,038	257,038	13.62	18,872	Spain	483	42	1.4
Makati	510,383	408,306	27.36	18,654	Philippines	108	71	4.2
Naihati	215,303	172,242	11.55	18,641	India	23	108	7.9
Saint- Giles	46,931	46,931	2.52	18,623	Belgium	771	39	1
Macau	552,500	442,000	29.7	18,600	Macau	63	63	3.8
Cairo	6,758,581	5,406,865	374	18,071	Egypt	62	68	5.4
Beirut	331,366	265,093	20	18,063	Lebanon	62	68	5.4
Allahabad	1,142,722	914,178	63.38	18,030	India	23	108	7.9
Panhati	348,438	278,750	19.4	17,961	India	23	108	7.9
Malé	103,693	82,954	5.798	17,884	Maldives	108	71	4.2

Reference: http://en.wikipedia.org/wiki/list_of_cities_proper_by_population_density.
http://www.cisco.com/web/solution/sp/vni/mobile_forecast_highlights/index.html, Accessed 20 June 2013.

- a) that radio spectrum is the most important resource;
- b) that smart phone is penetrating rapidly as social universal service;
- c) that flat rate tariff is preferable to care of network neutrality and social utility;
- d) that traffic offload to microcell can mitigate the requirements for new radio spectrum allocations;

decides that the following guideline be established

1. What types of traffic offloading technology is preferable?
2. What is the relevant evaluation parameter for offloading to minimize spectrum resource and investment cost of radio base stations?
3. What is the preferable measure of offload characteristics, that is transparent and observable including bigdata?

8 Conclusion

For the solution of heavy traffic concentration problem in wireless cloud era, the traffic offloading to microcell and the offload guideline is calculated at Shibuya-ward of Tokyo metropolitan, as a high traffic concentrating area in Japan. Guideline is based on the cost minimization strategy of the radio base stations and limitation of existing spectrum resource. Calculated results show that the traffic offloading to microcell is necessary in 5 years, even if the LTE is implemented at all radio base stations. Obtained results are translated to the universal parameters for the global use, and applied to various congested cities in the world. Required offload years are calculated for the high population cities and wards in the world, and results show that the traffic offload should be done very near future, even if the cost down of macrocell mobile radio base stations are done. From the proposed guideline, it is required to obtain the parameter of monthly traffic per unit area. The parameter can be directly obtained from the bigdata analyses from the operating mobile carriers, and it may be better to establish monitoring system and methodology. It is recommended that the parameters are opened to users and regulatory body of radio spectrum, for the enhancement of social utility. Another indirect method is the estimation from the social and open bigdata analyses, and the method is applicable for the region in that mobile service operation carrier has no data. At the same time, the urgent and real implementation of offloading technology including wireless agents, and the offloading promotion are required now.

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