Practical Considerations in Trunk Engineering for Cellular Service*

Kyung Geun Lee[1], JongSuh Park[2], Ho Soo Kim[2], and Juwook Jang[2]

[1] Dept. of Information and Communication Engineering, Sejong University
`kglee@sejong.ac.kr`
`http://nrl.sejong.ac.kr`
[2] Department of Electronic Engineering, Sogang University
`{netofpos,lake}@eeca1.sogang.ac.kr`
`jjang@sogang.ac.kr`
`http://eeca2.sogang.ac.kr`

Abstract. We identify and address practical problems facing the engineers who are responsible for trunk engineering(determining optimal trunk requirements between switching systems in a telecommunications network) in a nation-wide cellular service. Currently, Erlang B formula is used to calculate the number of trunks to carry the estimated cellular traffic with given target grade of service(i. e. call block rate). However, our recent measurement at a nation-wide cellular service covering more than 15 million customers shows that the measured block rate is occasionally far greater than the expected block rate, as much as 8 times. Fearing this, it is a common practice for field engineers to assign far more trunks than dictated by the Erlang B formula. But the main problem is that there is no basis on how to assign more trunks. In this paper, we track the cause for excessive block rate by analyzing vast amount of call log to identify the characteristic of the recent cellular traffic. We introduce a simple but effective compensation method to adjust the Erlang B formula with random and non-random traffic. The second problem we address is that the Erlang B formula gives average block rate while the management of the cellular service demands the engineers to guarantee given upper limit to the block rate. We employ the concept of the confidence interval to guarantee given block rate with certain reliability. We develop a simulation program to derive an updated version of Erlang B table with the confidence interval and a simple heuristic method to compensate for the peakedness of contemporary cellular traffic.

1 Introduction

With explosive growth of cellular service, the cost of upgrading wired link capacity to carry the cellular traffic increases tremendously. Thus it is essential to accurately estimate the minimal capacity of the links needed for given target

---

* This work was supported in part by Sogang University Research Fund 2003 and uT frontier project.

H.-K. Kahng and S. Goto (Eds.): ICOIN 2004, LNCS 3090, pp. 544–552, 2004.

Grade of Service (GoS), often represented by the block rate for attempted call [2,3,4].

We evaluate the performance of the current traffic engineering criterion based on Erlang B formula leveraging vast amount of recent data from an operating cellular core network with over 15 million subscribers [1]. Also, we re-examine Erlang B assumptions and discuss whether Erlang B formula is appropriate on cellular core networks. We have chosen two CGS (Cellular Gateway System)s with most traffic and the MSC (Mobile Switching Center)s connected to them. Measurement is done in time scales of hours and seconds. Billing data in user profiles were processed to obtain the traffic volume at the resolution of seconds. We also developed a Block Generating Program (BGP) to get the results using billing data, similar to real network. Block rate has been measured and compared against the expected block rate from Erlang B table. In average, the measured block rate was higher than the expected block rate. To identify the cause of deviation, the traffic characteristic of the measured traffic is analyzed at the resolution of seconds and hours. The VMR (Variance to Mean Ratio) which represents the peakedness showed from 0.45 to 3.50 for seconds traffic. Erlang B table does not guarantee the target block rate but shows an average block rates. To guarantee the target block rate, we introduce compensated Erlang B Table had to be calculated by adding a new factor called *degree of confidence*, which enables one to specify the reliability of assigned trunks. This factor proves that current Erlang's B table corresponds to 50% in terms of degree of confidence.

The rest of the paper is organized as follows. Section 2 describes the measurement setup. Evaluation of current traffic engineering is performed in Section 3 by comparing the measured block rate against the expected block rate. Experiment in real network is analyzed in Section 4. In Section 4, we used COMNET and BGP simulation to overcome experimental limit in real network and proposed a method of compensation based on confidence rate to Erlang B table for Poisson and bursty traffics. Section 5 concludes this paper.

2 Measurement Setup

Figure 1 shows a typical configuration of telecommunication network supporting cellular phone traffic. Voice traffic from cellular phone is collected from base stations. *MSC (Mobile Switching Center)* is a hardware interface between a group of base stations and the wireline network. The traffic from MSCs may be aggregated into *CGS (Cellular Gateway System)*. Trunk engineering mainly concerns determining the capacity of links between MSCs and CGSs. We measured the traffic at each link connecting an MSC to a CGS at the resolution of seconds and hours.

The call processing capability per hour of the chosen switches is shown in Table 1.Two different types of measurement are performed. The first type is to record number of incoming and outgoing calls per hour for each switch for 3 months.One problem with the first data set is that its resolution is in hours and

Table 1. Switch Specification

Specification	MSC	CGS
Call Processing Capacity per hour	315,000	1,050,000
Max. Number of E1 Lines supported	315	2,400

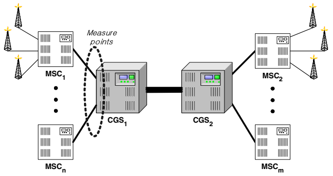


Fig. 1. General Topology of Cellular Service

only shows the aggregate number of calls for an hour. The second measurement is based on the billing data for each call and has the resolution of seconds.

3 Current Traffic Engineering Diagnostics

Current traffic engineering uses the Erlang B table to calculate the link capacity with a given target block rate. While the Erlang B table lists the amount of traffic (in the units of Erlang) to be carried for specific number of trunks at a target block rate, cellular service network uses E1 links with 31 trunks per each E1 link [3,8]. We compared the measured block rate represented in equation 1 against the expected block rate based on the Erlang B table.

$$P(block\ rate) = \frac{number\ of\ TRK\_BUSY\ signals}{number\ of\ call\ attempts\ per\ hour} \tag{1}$$

Blocking occurs whenever the number of calls, in or out, exceeds the number of trunks available to support them. It is used primarily for determining trunk quantities in first-choice trunk groups in which, if all trunks are busy, a call overflows to another group, or never returns [10].

Figure 2 compares the measured block rate against the expected block. Note that many points are close to the origin that represents zero block rate. This is due to the fact that most links are assigned the number of trunks far greater than needed since only multiples of E1 link can be leased (E1 link consists of

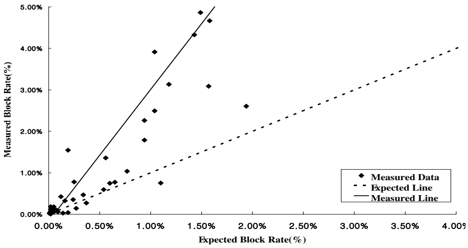


Fig. 2. Measured vs. Expected Block Rates

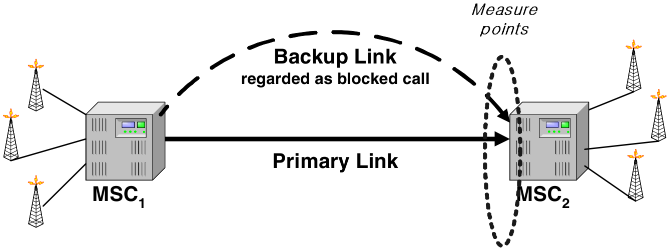


Fig. 3. Experimental Link Setup

31 trunks). The solid line represents a linear regression of the points while the broken line represents the expected line. If blocking occurs as expected from the Erlang's B formula the points should be clustered along the broken line. However, the points in Figure 2 show clear deviation from the expected line.

3.1 Methodology

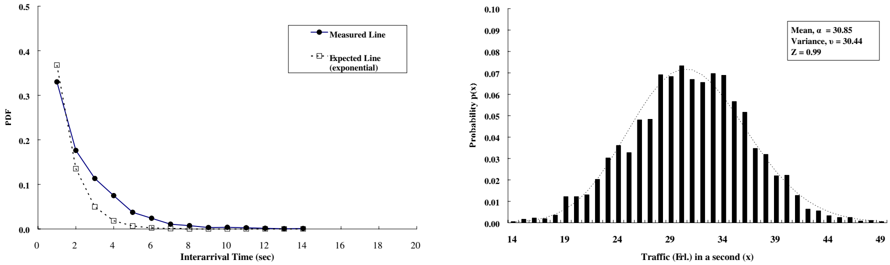
Because the current service cellular system is overprovisioned mostly to 0.1% target block rate, it is difficult to analyze the behavior the block rate. To examine the behavior of incoming calls and block rate, we have setup a experimental link as seen in Figure 3. The primary link which normally operates as main path, and the backup link which runs as alternative route that when calls are blocked from the main link they are returned to the alternative link and considered as blocked calls. The data at the resolution of seconds were gathered from the billing data that also records attempted calls (not all switching systems records attempted calls).

3.2 Analysis of Inter-arrival Times and VMR

To find this reason, we analyzed 1) Inter-arrival time distribution 2) VMR (variance to mean ratio) using billing data of each sample. It is useful for calculating skewness of nonrandom traffic [7,8,9,11]. In order to check whether the sample traffic follows Poisson distribution, we proved it with chi-square goodness-of-fit test for call inter-arrival time [5,13].

Figure 4 compares the PDF of the measured traffic against that of the inter-arrival times for the traffic measured at the resolution of seconds resembles the Poisson arrival. Chi Square verification can be used for determining if the traffic complies with the Poisson distribution, but we cannot conclude the characteristics of the traffic with it. Therefore, we analyzed VMR using billing data in order to get the traffic characteristics of the sample.

Peakedness of traffic has been found a useful characterization tool in blocking approximations and in trunk theory. The peakedness factor Z for any link is obtained by calculating the variance-to-mean ratio of the busy-hour traffic, as in



(a) Measured Traffic vs. Poisson traffic (b) PDF of the measured traffic

Fig. 4. Traffic Measurement Results

Equation 2. If Z is less than 1, the traffic is defined as *smooth* and it experiences less blocking than Poisson traffic. If the Z is larger than 1, then it is called *peaked* traffic and it experiences larger blocking than Poisson traffic [2,3,6,12,13].

$$Z = \frac{v}{\alpha} \tag{2}$$

4 Simulation

4.1 Compensation of Erlang's B Table

Erlang's B Table with Degree of Confidence for Random Traffic With the help of these results from the simulation we were able to add a new parameter to Erlang's B Table, called the degree of confidence.The block rate resulted a normal distribution which was possible to define the degree of confidence at different interval of the distribution. Table 3 shows the result of reassigned Erlang's B table adding degree of confidence from Table 2. It shows how much margins is needed to assure call blocks. Normal Erlang's B table resulted 50% of confidence which means that the target block rate can only support 50% of the measured block rate. So to allow more confidence, for example, if a service company wants the target block rate at 99% of confidence for 50Erl traffic they must add 6.5% more based on standard Erlang's B Table.

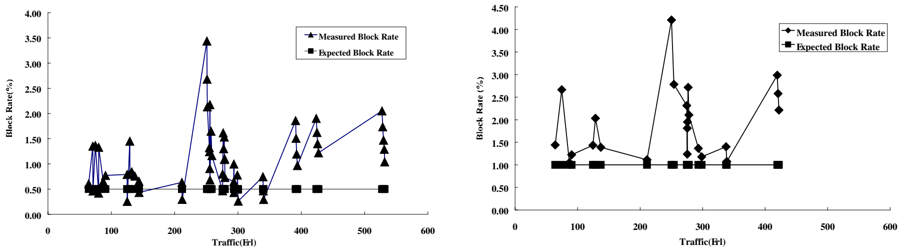
BGP (Block Generating Program) The flow of BGP process is divided into three steps. First gathering original billing data in seconds, second generating these data in BGP simulator and as a result we get attempted calls, AHT, traffic, block calls, block rate, etc from original billing data at different trunks we have set. Traffic characteristics percentage resulted as 22% for smooth 50% poisson and 28% peaked. We analyzed traffic characteristic applying VMR for billing data of total 108 samples. In results, VMR had a value from 0.48 to 3.50.

Table 2. Margin rate at different degree of confidence

1%	Margin Rate							
Block Rate	Degree of Confidence							
Traffic	99.9	99	95	90	80	70	60	50
50	7.8	6.3	4.7	3.1	3.1	1.8	1.8	0.0
1000	0.5	0.5	0.2	0.0	0.0	0.0	0.0	0.0

Table 3. Updated number of trunks using table 2

1%	Updated Number of Trunk					
Block Rate	Normal Distribution					
Traffic	Erlang B	99.9	80	70	60	50
50	64	69	66	65	65	64
1000	1029	1034	1029	1029	1029	1029



(a) Peaked traffic (0.5%) (b) Peaked traffic (1%)

Fig. 5. Measured block rate vs Expected block rate for Traffic characteristics

BGP Simulation Results Figure 5 shows one of the pattern of block rates at different traffic characteristics. It shows simulated block rates when the target block rate of 0.5% and 1%, and actually we compared the Erlang B expected block rate.

4.2 Compensation of Erlang B Table for Non-random Traffic

Heuristic Method We have derived a heuristic method in assigning trunks for peaked traffic.The three variables involved are traffic (T), block rate (B) and lines (L). Traffic (in Erlangs) is the traffic generated every hour and was collected during the busiest hour of operation of a cellular core system. Block rate is the percentage of dropped calls due to an insufficient number of lines being available. Lines are the number of trunks assigned. We proceed the following procedure to get the compensation factor.Steps of assigning L_C at diffrerent degree of confidence line L_E is the amount that Erlang B expects from the pertinent

Table 4. Compensation factor

1% Block Rate	Traffic (Erlang)	Degree of confidence (%)				
		99.9	90	80	70	60
Compensation Factor F	˜180	6.7	4.5	3.3	2.0	2.1
	180˜360	7.7	5.1	3.7	3.3	2.3
	360 ˜	4.7	4.7	3.8	3.8	3.1

Table 5. Reassigned trunk applying compensation factor

1% Block Rate		Degree of confidence (%)				
Traffic	Erlang B	99.9	90	80	70	60
50	64	68	67	66	65	65
200	221	238	232	229	228	226
500	527	552	552	547	547	543

traffic and block rate, and line L_C is the compensation line that prevents all the possible blocks. Figure 6 shows results of block rate against traffic. Setting line L_C at different level we can calculate the degree of confidence.

$$L_E = Erl(T_M, B_E, x) \tag{3}$$

$$T_C = Erl(y, L_E, B_M) \tag{4}$$

$$L_C = Erl(T_C, B_E, z) \tag{5}$$

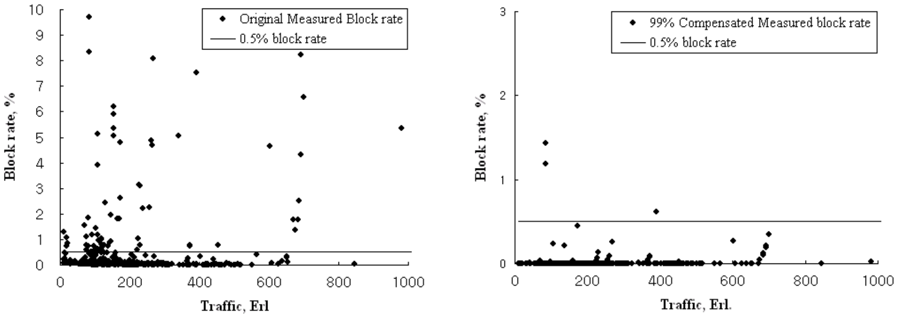
$$F = \frac{(L_C - L_E)}{L_E} * 100 \tag{6}$$

B_M stands for measured block rate, T_C is the measured traffic, B_E expected block rate, L_E expected line T_C compensated traffic and L_C for compensated line.As a result we can get the compensation factor by calculating the ratio of L_E, Erlang B expected line and L_C, derived from equation 3. F ,the compensation factor (%), is derived from Equation 6 .

Applying equation 3,4,5 and 6 the results of compensation factor are listed in Table 4. And with this factor we reassigned trunks as seen in Table 5. The results satisfied after applying heuristic method in real network. Fig 6(b) had a 96% satisfaction over 99%.

5 Conclusion

In this paper we have analyzed Erlang B theory which is currently used in cellular core networks. Experiment and analysis were made with real data in real networks. Compensation of Erlang B Table under the results of simulation.



(a) Original Measure Block Rate (b) 99% compensated

Fig. 6. Results applying in real network

Adding a new factor, degree of confidence reassigning Erlang B table. Block Generating Program was made to get results similar to real experiment using billing data. Block rate tends to be higher than the expected block rate form Erlang B currently in use. Non-poisson traffic that is bursty takes up about 30% for cellular core networks. Poisson and bursty traffic occupied 80% of total traffic, and Erlang B table needs to be compensated in order to be applied to cellular core networks.

According to our analysis, Erlang B theoretical block rate is not identical to measured block rate, and we concluded that it is due to the traffic characteristics. Therefore, we added the degree of confidence to Erlang's B table for communication quality and enables service companies to consider directly some variables such as communication quality and cost as they assign trunks. We introduced alternative calculation method,such as heuristic that considers VMR value including peakedness effects.

References

[1] SK Telecom, “Annual Report 2001”, http://www.sktelecom.co.kr/english/index.html, 2001.

[2] James R. Boucher ”Traffic System Design Handbook: Timesaving Telecommunication Traffic Tables and Programs”, IEEE Press, pp. 1-78, 1993.

[3] Haruo Akimaru, Konosuke Kawashima, ” Teletraffic- Theory and Applications”, 2nd Edition, Springer Verlag, pp3-55, January 1993.

[4] Villy B. Iversen, “Teletraffic Engineering Handbook”, ITU-D SG 2/16 & ITC, 2002-09-06.

[5] Robert S. Cahn ”Wide Area Network Design - Concepts and Tools for Optimization”, Morgan Kaufman Publishers, Inc, pp. 11-142, 1998.

[6] Derek Lam, Donald C. Cox, Jennifer Widom, “Teletraffic Modeling for Personal Communications Services”, IEEE Communications Magazine, pp79-87, February 1997.

[7] S. Molnar, Gy. Miklos, "Peakedness Characterization in Teletraffic", IFIP TC6, WG6.3 conference Performance of Information and Communications Systems, PICS'98 Lund, Sweden, May 25-28, 1998
[8] Richard Parkinson, "Traffic Engineering Techniques in Telecommunications", INFOTEL SYSTEMS CORP. http://www.infotel-systems.com.
[9] D.Everitt, "Traffic capacity of cellular mobile communications systems" Computer Networks and ISDN Systems, 20, 447-454, 1990.
[10] F.Barcelo and J.Jordan. "Channel holding time distribution in cellular telephony." The 9th International Conference on Wireless Communications (Wireless'97), Vol. 1,pp.125-134,Alberta,Canada, 9-11 July, 1997.
[11] Yuguang Fang, Imrich Chlamtac. "Teletraffic Analysis and Mobility Modeling of PCS Networks" IEEE 1999.
[12] Roger I. Wilkinson, "Theories for Toll Traffic Engineering in the U. S.A", Bell System Technical Journal, vol. 35, pp. 421–513, 1956.
[13] Victor S. Frost, Benjamin Melamed, "Traffic Modeling For Telecommunications Networks", IEEE Communications Magazine, pp 70-81. March 1994.