

THE CORRELATION EFFECTS ON SERVICE CONTROL POINT RESPONSE TIME

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SUMMARY

As the centralized database for the integration across multiple wireless tiers and wireline access, traffic design considerations for SCP performance measurement are of great important in the personal communications era. By neglecting the effect of disk access time, the SCP response time R includes the SCP processing time P and signalling link delay L only. A bivariate normal distribution has been proposed for modelling (P, L) such that some statistical estimations of L given P can be conveniently obtained in different combination of SCP processing load and link utilization. Further, the correlation effects of $(P, L | P = p)$ on R are investigated. After a *Tukey one degree of freedom test* with one observation of $\mu_{L|P=p}$ per treatment ($n = 1$) under different normalized processing times and correlations, the two-factor ANOVA model becomes an interaction model without pure error effects due to the computed F^* values being significantly greater than the critical $F(0.95; 1, 11)$. Besides, rejection threshold criteria of SCP response time with minimum loss rate (0.01 per cent) of messages are proposed to ensure a good service quality of SCP.

KEY WORDS: correlation effects; IN; overload control; response time; SCP

1. INTRODUCTION

An intelligent network (IN) is a large and complex telecommunication system.¹⁻³ It consists of many distributed elements such as service switching points (SSPs),⁴ service control points (SCPs),⁵ service management system (SMS), and service creation environment (SCE). As the service logic and customer data are stored, the SCP is the brain of an IN. A desired SCP is an on-line, fault-tolerant, and real-time database system. Design considerations for SCP performance measurement are of great importance, especially while the SCP is considered as a centralized database for the integration across multiple wireless tiers and wireline access in the personal communications era.⁶⁻⁸

Traffic congestion management is an essential procedure⁵ of SCP in order to guarantee some deserved performance under unpredictable and changing traffic conditions. An SCP receives the traffic (i.e. query messages) from SSPs and is expected to respond to those messages within agreed time-out values. If an SCP response message does

not arrive before the timer expires, the SSP will initiate some failure actions. In addition, the SCP also takes measurements⁵ from average response time, lost calls by the SCP due to excessive delays, and some specific performance index for preventing congestion. Therefore, the congestion threshold of SCP is defined to be the most severe overload level indicated by the measurements.

Upon overload occurring, the SCP has two traffic regulation approaches,⁵ non-selective ACG (automatic code gap) control and selective ACG control, to throttle the traffic. These two approaches are both application level ACG control to selectively screen excess traffic from the signalling network. Essentially, an ACG restrictive control approach employed in the SCP is a back-pressure mechanism^{9,10} in order to guarantee that no SSPs will initiate more queries than the SCP can absorb. There is a trade-off relationship between the regulation level of the SSPs traffic and the improvement of IN performance.¹¹

Recently, there have been many traffic regulation approaches employed in the high speed network.^{9,12,13} However, these congestion control approaches distributively regulate each source within its allowable rate that is impractical for an

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SCP. Since the SCP is a brain of the IN, it itself is a traffic regulation centre. The SCP should regulate the network traffic autonomously and in a timely manner.

The SCP response time as well as the propagation time between SSP and SCP will directly affect the service quality of an IN call.⁴ Since the propagation time is approximately a constant value, the SCP response time consequently becomes the major factor affecting the service quality. The eventual target to ensure a good service quality of SCP is a good response time measurement indicator to detect an abnormal performance and a rejection threshold of SCP response time to throttle the expired messages.

In this paper, the SCP response time will be statistically studied. In Section 2, features of response time components will be introduced. In Section 3, a bivariate normal distribution¹⁴ will be proposed for modelling the response time components so as to investigate the correlation effects on SCP response time. In Section 4, rejection threshold criteria of SCP response time will be proposed as an SCP congestion management threshold¹⁵ for ensuring a good service quality of SCP. Finally, some important conclusions will be given and discussed.

2. RESPONSE TIME COMPONENTS

The requirement for SCP is real-time, high availability and fault tolerance.³ For this stringent performance requirement, the SCP response time should be controlled efficiently and accurately. Clearly, SCP response time is defined as the time interval from the moment when the last bit of a query-related message enters the SCP, to the moment when the last bit of a response message leaves the SCP. The SCP response time R includes the SCP processing time P , disk access time D , and signalling delay link L as described below.⁵

2.1. SCP processing time

The SCP processing time is decomposed into platform processing time and application processing time. We consider the SCP processing time as a unit here and define it as the time interval from the moment when the last bit of a message enters the SCP, to the moment when the last bit of a message is placed on the transmission buffer of the signalling link, excluding the time taken to perform any disk access. The SCP processing time P is assumed to be normally distributed with the probability density function (p.d.f.) given by

$$f_P(p) = \frac{1}{\sigma_P \sqrt{2\pi}} e^{-\frac{1}{2} \left(\frac{p - \mu_P}{\sigma_P} \right)^2}, p \geq 0$$

$$= 0, \text{ elsewhere.}$$

Bellcore⁵ proposed the means and the .95th quantiles of an SCP processing time at 40 and 80 per

cent of maximum SCP capacity. Accordingly, the standard deviations of processing time can be estimated as summarized in Table I.

2.2. Disk access time

Most conventional database systems are disk resident. For real-time constraints in telecommunication applications, disk data may be cached into memory for fast access.¹⁶ Obviously, the access time for main memory is orders of magnitude less than for disk storage. In the response of SCP to SSP, all service logic programs (SLPs)¹⁷ and the related data are memory resident. This means that the SCP is designed as a main memory database system with the related data residing permanently in main physical memory. Therefore, no disk access time will affect the SCP response time. However, if the multiple disk access is required in the processing of query-related messages, then each disk access is assumed to be 30 ms or less.

2.3. Signalling link delay

We assume each SS7 (signalling system number 7) link with 64 kb/s link speed operating under a steady-stage traffic load.¹⁸ A non-pre-emptive priority queuing discipline¹⁹ is used to examine delay characteristics of the signalling message traffic. The signalling link delay is defined as the time interval from the moment when the last bit of an SCP response message is placed on the transmission buffer of a signalling link, to the moment when the last bit of this message is transmitted to the outgoing signalling link. Again, the signalling link delay is assumed to be normally distributed, with the p.d.f. given by

$$f_L(l) = \frac{1}{\sigma_L \sqrt{2\pi}} e^{-\frac{1}{2} \left(\frac{l - \mu_L}{\sigma_L} \right)^2}, l \geq 0$$

$$= 0, \text{ elsewhere.}$$

The signalling link delay is decomposed into the message queuing delay and the message emission delay. Since the queuing delay is a function of link utilization and the message length distribution, emission delay is a function of the signalling link speed and the message length distribution. The signalling link delay objectives calculated using the $M/G/1$ queuing formula for link delay at 0.4 and 0.8 Erlangs of link utilization for 279 octets' message at 64 kb/s

Table I. SCP processing time based on Bellcore's data

Percentage of maximum SCP capacity	μ_P , ms	σ_P , ms	.95th quantile, ms
40	150	18.24	180
80	180	21.88	216

of link speed²⁰ can be estimated as summarized in Table II.

3. CORRELATION EFFECTS

As mentioned above, a conventional analysis of response time components is based on the normally independent distribution for each variable. This assumption implies that the SCP response time is normally distributed and the variance of SCP response time is the sum of the variances of the response time components, $\text{Var}(R) = \text{Var}(P) + \text{Var}(L) + \text{Var}(D)$. However, the value of the correlation coefficient between response time components is positive. For instance, a long query message results in long processing time and produces a long response message to the signalling link. For a main memory SCP system, there is no disk access time, then we have

$$R = P + L, \quad \text{and} \quad E[R] = E[P] + E[L] \quad (1)$$

The variance of R , $\text{Var}(R) = \text{Var}(P) + \text{Var}(L) + 2\text{Cov}(P, L)$

$$= \sigma_P^2 + \sigma_L^2 + 2\rho\sigma_P\sigma_L$$

where $\rho = \rho_{P,L}$.

3.1. Modelling the SCP response time

Let the two-dimensional random variable (P, L) have the joint probability density function

$$f_{P,L}(p,l) = \frac{1}{2\pi\sigma_P\sigma_L\sqrt{1-\rho^2}} \exp \left(-\frac{1}{2(1-\rho^2)} \left[\left(\frac{p-\mu_P}{\sigma_P} \right)^2 - 2\rho \left(\frac{p-\mu_P}{\sigma_P} \right) \left(\frac{l-\mu_L}{\sigma_L} \right) + \left(\frac{l-\mu_L}{\sigma_L} \right)^2 \right] \right) \quad (2)$$

where $0 < p < \infty$, $0 < l < \infty$, $\sigma_P > 0$, $\sigma_L > 0$ and $|\rho| < 1$.

Equation (2) is called a bivariate normal distribution. Then, the marginal distributions of SCP processing time P and signalling link delay L are univar-

iate normal distributions. Further, we have

Theorem 1. If (P, L) has a bivariate normal distribution, then the conditional distribution of L given $P = p$ is normal with mean

$$\mu_{L|P=p} = \mu_L + \left(\frac{\rho\sigma_L}{\sigma_P} \right) (p - \mu_P)$$

and variance $\sigma_{L|P=p}^2 = \sigma_L^2(1 - \rho^2)$.

By Theorem 1, we have the conditional p.d.f.

$$f_{L|P}(l|p) = \frac{1}{\sigma_L\sqrt{(2\pi)}\sqrt{(1-\rho^2)}} e^{-\frac{1}{2} \left[\frac{l - \mu_L - \rho \frac{\sigma_L}{\sigma_P} (p - \mu_P)}{\sigma_L\sqrt{(1-\rho^2)}} \right]^2} \quad (3)$$

For $1 - \alpha = 0.95$, we have $z_{1-\alpha} = 1.645$ and the .95th quantile of L at given $P = p$ can be estimated by

$$l_{0.95} \equiv 1.645\sigma_L\sqrt{(1-\rho^2)} + \mu_L + \rho\sigma_L\left(\frac{p-\mu_P}{\sigma_P}\right)$$

If $\Psi \times \Omega$ represents the combination of SCP processing load and link utilization as follows:

$$\Psi = \begin{cases} V, & 40 \text{ per cent of the maximum SCP capacity} \\ W, & 80 \text{ per cent of the maximum SCP capacity} \end{cases}$$

and

$$\Omega = \begin{cases} V, & 0.4 \text{ Erlangs of link utilization} \\ \text{for 279 octets message at 64kb/s of link speed} \\ W, & 0.8 \text{ Erlangs of link utilization} \\ \text{for 279 octets message at 64kb/s of link speed} \end{cases}$$

Estimation of the .95th quantile of L given $P = p$ is plotted against p , as shown in Figure 1. It appears that the SCP capacity has no effect on predicted quantiles. However, the correlation does have some effect on the predicted .95th quantiles of L given $P = p$ with an increment about 25 per cent under high link utilization conditions.

Further, the conditional mean

$$\mu_{L|P=p} = \mu_L + \rho\sigma_L\left(\frac{p-\mu_P}{\sigma_P}\right)$$

is plotted against p under various ρ values, as shown in Figure 2. Here, the two horizontal lines are exactly the Bellcore values. It is found that the conditional mean of L is a monotonic increasing linear function of correlation coefficient, especially under high link utilization.

3.2. Independence of response time components

By conventional analysis with an assumption of stochastic independence of P and L , we have

Table II. The signalling link delay based on Bellcore's data

Link utilization, Erlangs	μ_L , ms	σ_L , ms	.95th quantile, ms
0.4	47	25.53	89
0.8	107	99.69	271

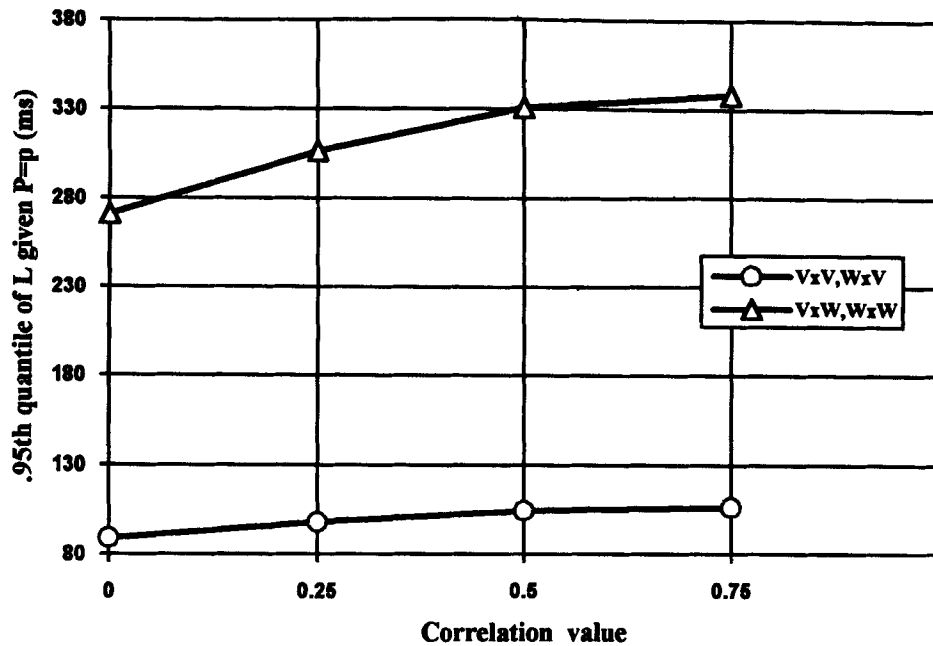


Figure 1. Estimation of the .95th quantile of L given $P = p$

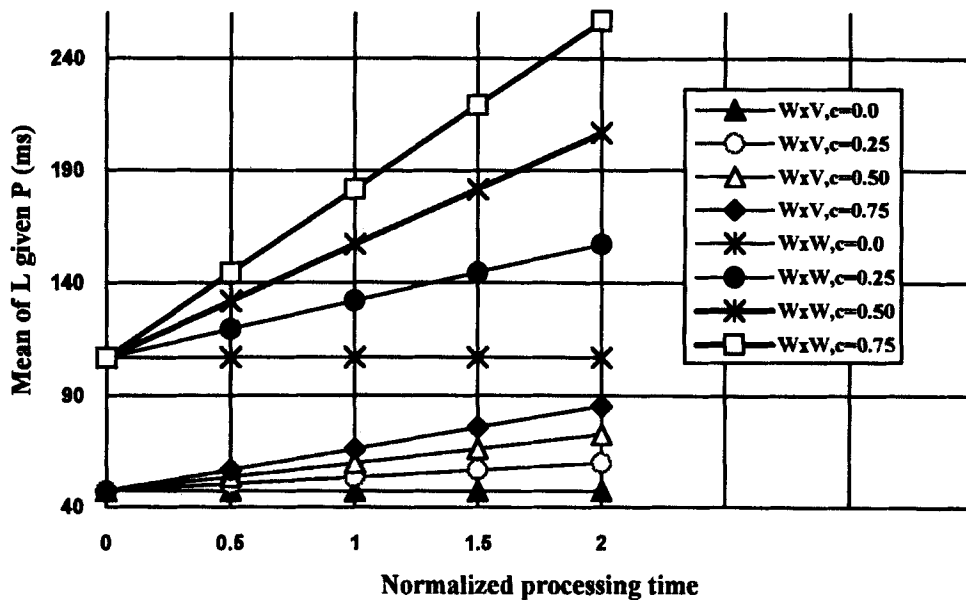


Figure 2. Estimation of the conditional mean of L given $P = p$ (c denotes correlation)

Theorem 2. If (P, L) has a bivariate normal distribution, then P and L are independent if and only if P and L are uncorrelated.

By Theorem 2, it can be observed that if $\rho = 0$, the joint density of equation (2) becomes the product of two univariate normal distributions. Thus $E[R] = E[P] + E[L]$ and $\text{Var}(R) = \text{Var}(P) + \text{Var}(L)$. Therefore, SCP response time based on Bellcore's data can be estimated as summarized in Table III.

Table III. SCP response time based on Bellcore's data

Ψ	Ω	$\mu_R = \mu_P + \mu_L, \text{ ms}$	$\sigma_R = \sqrt{(\sigma_P^2 + \sigma_L^2)}, \text{ ms}$.95th quantile, ms
V	V	197	31.38	248.62
V	W	257	101.35	423.72
W	V	227	33.62	282.30
W	W	287	102.07	454.91

3.3. Correlation effects of response time components

Correlation effect of $(P, L|P = p)$ on response time R will be investigated as follows: $E[R] = E[P] + E[L] = E[P] + E\{E[L|P = p]\}$

$$= \mu_P + \left[\mu_L + \rho\sigma_L \left(\frac{p - \mu_P}{\sigma_P} \right) \right] \quad (4)$$

By Theorem 1, the values of $E[L|P = p]$ are

Table IV. One observation of $\mu_{L|P=p}$ per treatment ($n = 1$)

Normalized P (factor A)	Correlation ρ (factor B)				Average
	0.00 (j = 1)	0.25 (j = 2)	0.50 (j = 3)	0.75 (j = 4)	
(a) Mean of L given P = p (ms) for (V×V, W×V)					
0.0 (i = 1)	47.00	47.00	47.00	47.00	47.00
0.5 (i = 2)	47.00	50.19	53.38	56.57	51.78
1.0 (i = 3)	47.00	53.38	59.77	66.15	56.57
1.5 (i = 4)	47.00	56.57	66.15	75.72	61.36
2.0 (i = 5)	47.00	59.77	72.53	85.30	66.15
Average	47.00	53.38	59.76	66.14	56.57
(b) Mean of L given P = p (ms) for (V×W, W×W)					
0.0 (i = 1)	107.00	107.00	107.00	107.00	107.00
0.5 (i = 2)	107.00	119.46	131.92	144.38	125.69
1.0 (i = 3)	107.00	131.92	156.85	181.77	144.38
1.5 (i = 4)	107.00	144.38	181.77	219.15	163.07
2.0 (i = 5)	107.00	156.85	206.69	256.54	181.77
Average	107.00	131.92	156.84	181.76	144.38

affected by ρ and normalized SCP processing time P. With one observation of $E[L|P = p]$ per treatment ($n = 1$) under different normalized processing times and correlations as shown in Table IV,²¹ the interactions cannot be included in the two-factor ANOVA (analysis of variance) model.²²

However, by the Tukey one degree of freedom test for interactions,^{21,22} the computed F^* values are significantly greater than the critical $F(0.95; 1, 11)$ due to SSPE (pure error sum of squares = error sum of squares - interaction sum of squares) being relatively close to zero. Therefore, the two-factor ANOVA becomes an interaction model without pure error effects as shown in Table V.²¹

If $\rho = 0$, Equation (4) is reduced to equation (1) with results given in Table III. If $\rho \neq 0$, $E[R]$ is a linear function of ρ . Computations of $E[R]$ are plotted against $\Psi \times \Omega$ and different ρ values as shown in Figure 3. It is found that $E[R]$ is a monotonic increasing linear function of ρ . The effect of the link utilization on $E[R]$ is similar to that of ρ . For

instance with $p = F_P^{-1}(0.95)$ under $W \times W$ and $\rho = 0.75$, we have $\mu_R = 409.993$ ms. This value is about 142 per cent of μ_R based on Bellcore's data.

4. RESPONSE TIME THRESHOLD

4.1. Threshold derivation

It is clear that the signalling link delay can be predicted by given SCP processing time. If the estimated response time R is over a threshold, the message will be discarded. Elsewhere, the message will be placed on the transmission buffer of the signalling link. Therefore, it is required to estimate rejection thresholds so as to prevent expired messages from being sent across the network.

Assume that the SCP will lose one message from 10,000 messages received.⁵ By assuming that $F_R(r) \geq (1 - \alpha)$ with $\alpha = (1/10,000)$, we have

$$\Pr(P + L \leq r) \geq (1 - \alpha) \tag{5}$$

According to the probability theory with $r = p + l$, equation (5) can be reduced to $\Pr(P \leq p)\Pr(L \leq l|P \leq p) \geq (1 - \alpha)$. Since $0 \leq F(.) \leq 1$, we have

$$F_P(p) \geq (1 - \frac{\alpha}{2}) \text{ and } F_{L|P}(l|p) \geq (1 - \frac{\alpha}{2})$$

Therefore, the $(1 - (\alpha/2))$ th quantiles can be derived and given as follows:

$$\begin{aligned} p' &= z_{1-\frac{\alpha}{2}} \sigma_P + \mu_P \text{ and} \\ l' &= z_{1-\frac{\alpha}{2}} \sigma_L \sqrt{(1 - \rho^2)} \\ &+ \mu_L + \rho \sigma_L \left(\frac{p - \mu_P}{\sigma_P} \right) \end{aligned} \tag{6}$$

with rejection threshold criteria of $p \geq p'$ and $l \geq l'$.

Theorem 3. Let two random variables (P, L) have a joint p.d.f. is in equation (2) and satisfy the

Table V. Two-factor interaction model without pure errors

Source of variation	SS	d.f.	MS	Computed F^*	Critical F	Conclusions
(a) ANOVA table after Tukey one degree of freedom test for (V×V, W×V)						
Normalized P	916.81	4	229.2	5.41	$F(0.95; 4, 12) = 3.26$	reject $H_0(A)$
ρ	1018.50	3	339.5	8.01	$F(0.95; 3, 12) = 3.49$	reject $H_0(B)$
Interactions	509.32	12	42.4			
Total	2,444.63	19				
(b) ANOVA table after Turkey one degree of freedom test for (V×W, W×W)						
Normalized P	13,976	4	3494	5.40	$F(0.95; 4, 12) = 3.26$	reject $H_0(A)$
ρ	15,529	3	5176	8.00	$F(0.95; 3, 12) = 3.49$	reject $H_0(B)$
Interactions	7,765	12	647			
Total	37,270	19				

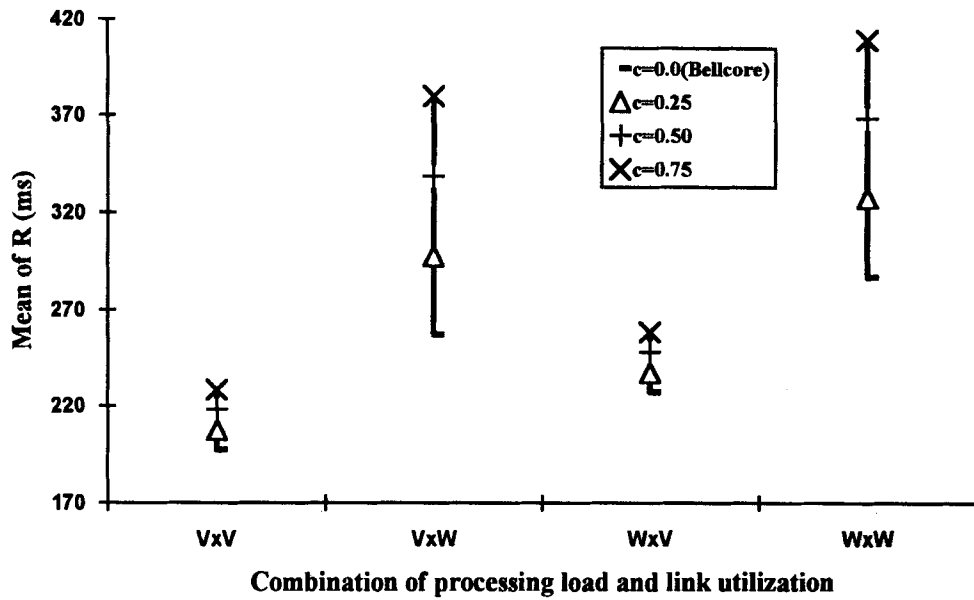


Figure 3. Calculated $E[R]$ at $p = F^{-1}(0.95)$ (c denotes correlation)

properties of Theorem 1 and Theorem 2, then SCP response time be calculated by equation (4). In addition, under the recommended service quality of SCP, we have two criteria: by criterion p' in equation (6), the processed message will be discarded in advance, and by criterion l' in equation (6), the signalling link delay time can be precalculated for predicting the response time, so that the processed message will be discarded.

Some rejection thresholds for SCP response time components have been estimated, and are summarized in Table VI. Therefore the SCP response time components can be predetermined for the SCP performance design so as to ensure the service quality of SCP even with the worst condition of SCP processing load and link utilization. Therefore, an expired message can be prevented from being sent across the network.

Table VI. Estimation of rejection thresholds

Response time criterion	Rejection threshold	Rejection thresholds estimated for components
P	$p \geq p'$	$W \times W \rho = 0.00: p' = 265.14(\text{ms})$
		$W \times W \rho = 0.25: p' = 265.14(\text{ms})$
		$W \times W \rho = 0.50: p' = 265.14(\text{ms})$
		$W \times W \rho = 0.75: p' = 265.14(\text{ms})$
$L P = p$	$l \geq l'$	$W \times W \rho = 0.00: l' = 494.89(\text{ms})$
		$W \times W \rho = 0.25: l' = 579.55(\text{ms})$
		$W \times W \rho = 0.50: l' = 636.87(\text{ms})$
		$W \times W \rho = 0.75: l' = 654.49(\text{ms})$
R	$r \geq r'$	$W \times W \rho = 0.00: r' = 760.03(\text{ms})$
		$W \times W \rho = 0.25: r' = 844.69(\text{ms})$
		$W \times W \rho = 0.50: r' = 902.01(\text{ms})$
		$W \times W \rho = 0.75: r' = 919.62(\text{ms})$

4.2. Numerical example

According to the investigation of statistical properties of the SCP response time, we demonstrate a preliminary analysis as follows. Let T be the agreed time-out value in seconds between an SSP and the SCP, λ be the arrival rate in messages per second, S be the mean service time in seconds per message, I be the traffic intensity, where $I = \lambda S$, and τ be the reflection time, $\tau = T -$ threshold value.

A reflection time is the time for adaptive, timely traffic regulation control. Observing the value of τ , it is easy to find that the larger value of τ regulates the traffic more instantly.

As a numerical analysis, let $T = 2000$ ms, $I = 0.8$, and $r' = 919.62$ ms, we have $\tau = T - r' = 1080.38$ ms. Therefore, this reflection time τ can regulate the congestion traffic

$$\phi = \left[\frac{\lambda_{r'} - \lambda_T}{\lambda_T} \right] = \left\{ \frac{\left[\frac{I}{r'} - \frac{I}{T} \right]}{\left(\frac{I}{T} \right)} \right\} = 117.48 \text{ per cent}$$

Again, by Theorem 2 the message can be detected and discarded due to the excess of $p' = 265.14$ ms. In this case, the reflection time $\tau = T - p' = 1734.86$ ms and $\phi = 654.318$ per cent. This dramatically increasing rate shows the effectiveness of our rejection threshold for traffic regulation.

5. CONCLUSIONS

A bivariate normal distribution has been proposed for modelling the SCP processing time P and signal-

ling link delay L of a main memory database SCP. It is found that ρ does have some effect on the predicted .95th quantiles of L given $P = p$ with an increment to about 25 per cent under high link utilization condition. Further, the correlation effects of $(P, L | P = p)$ on R are investigated. With one observation of $E[L | P = p]$ per treatment ($n = 1$) under different normalized processing times and correlations, the interactions cannot be included in the two-factor ANOVA model. However, this two-factor ANOVA model becomes an interaction model without pure error effects after the Tukey one degree of freedom test due to the computed F^* values being significantly greater than the critical $F(0.95; 1, 11)$. Finally, the rejection threshold criteria of R proposed to detect an abnormal performance and to throttle the expired messages will be enable us to ensure a good service quality of SCP.

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REFERENCES

1. J. M. Duran and J. Visser, 'International standards for intelligent networks', *IEEE Commun. Mag.*, **30**, (2), 34-42 (1992).
2. J. J. Garrahan, P. A. Russo, K. Kitami and R. Kung, 'Intelligent network overview', *IEEE Commun. Mag.*, **31**, (4), 30-36 (1993).
3. R. B. Robrock II, 'The intelligent network—changing the face of telecommunications', *Proc. IEEE*, **79**, 7-20 (1991).
4. Bellcore, Advanced Intelligent Network (AIN) Release 1 Switching Systems Generic Requirements, *TA-NWT-001123*, Issue 1, May 1991.
5. Bellcore, Advanced Intelligent Network (AIN) Release 1 Service Control Point Generic Requirements, *TA-NWT-001125*, Issue 1, May 1991.
6. G. P. Pollini, K. S. Meier-Hellstern and D. J. Goodman, 'Signaling traffic volume generated by mobile and personal communications', *IEEE Commun. Mag.*, **33**, (6), 60-65 (1995).
7. P. E. Wirth, 'Teletraffic implications of database architectures in mobile and personal communications', *IEEE Commun. Mag.*, **33**, (6), 54-59 (1995).
8. J. F. Rizzo and N. R. Sollenberger, 'Multitier wireless access', *IEEE Personal Commun.*, **2**, (3), 18-30 (1995).
9. K. Sohraby and M. Sidi, 'On the performance of bursty and modulated sources subject to leaky bucket rate-based access control schemes', *IEEE Trans. Commun.*, **42**, (2/3/4), 477-487 (1994).
10. X. H. Pham and R. Betts, 'Congestion control for intelligent networks', *Computer Networks and ISDN System*, (26), 511-524 (1994).
11. R. Kawahara, T. Asaka and S. Sumita, 'Overload control for the intelligent network and its analysis by simulation', *IEICE Trans. Commun.*, **E78-B**, (4), 494-503 (1995).
12. M. Abdelaziz and I. Stavrakakis, 'Some optimal traffic regulation schemes for ATM networks: a Markov decision approach', *IEEE/ACM Trans. Networking*, **2**, (5), 508-519 (1994).
13. D. E. Smith, 'Effects of feedback delay on the performance of the transfer-controlled procedure in controlling CCS network overloads', *IEEE J. Select. Area Commun.*, **12**, (3), 424-432 (1994).
14. A. M. Mood, F. A. Graybill and D. C. Boes, *Introduction to the Theory of Statistics*, McGraw Hill Book Company, New York, 1974.
15. J. K. Wey, L. F. Sun and W. P. Yang, 'A new traffic regulation scheme for SCP', *Proc. ICC95*, Seoul, Korea, August 1995.
16. I. Ahn, 'Database issues in telecommunications management', *SIGMOD RECORD*, **23**, (1), 37-43 (1994).
17. Bellcore, Advanced Intelligent Network (AIN) Release 1 Service Logic Execution Environment Generic Requirements, *TA-NWT-001124*, Issue 1, May 1991.
18. P. J. Kuehn, C. D. Pack and R. A. Skoog, 'Common channel signaling networks: past, present, future', *IEEE J. Select. Areas Commun.*, **12**, (3), 383-394 (1994).
19. G. Willmann and P. J. Kuehn, 'Performance modeling of signalling system no. 7', *IEEE Commun. Mag.*, **28**, (7), 44-56 (1990).
20. ITU-T, *Recommendation Q. 700-Q.706*, Geneva, 1989.
21. MINITAB Reference Manual—release 9 for Windows, Minitab Inc., July, 1993.
22. J. Neter and W. Wasserman, *Applied Linear Statistical Models—Regression, Analysis of Variance, and Experimental Designs*, Richard D. Irwin, Inc., Illinois, 1974.

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