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The Optimum Trunks Reservation Strategy for Dynamic Routing[1]

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Abstract: It is turned out that there exists the optimum trunks reservation strategy when the randomized and dynamic routing DAR-1 is adopted in the circuit-switched networks by modeling a theoretical simplex network and numerical calculating. Therefore, a quantitative formula between the optimum number of reserved circuits and added traffic on the given trunk capacity is derived from the statistical regression on a set of samples, the optimum reserved circuits, traffic loads and trunk capacities, which are obtained through simulating on various sized simplex networks. The formula simplifies monitoring functions and reduces large amount of calculations for the network management. Simulating on more general networks with 8 nodes by the real-time dynamic routing RTNR, we show that our reservation strategy is comparable with that of AT&T. Although the result is got from the circuit-switched networks, the research methodology could be used to the IP networks.

Key words: dynamic routing, congestion control, trunks reservation, network simulation.

1. INTRODUCTION

Early 90s of last century, many dynamic routing algorithms were developed by the big telecom corporations, such as DNHR and RTNR of AT&T, DCR of North Telecom, STR of NTT, DAR of BT [1-8], and etc.

As we know that, dynamic routing increases the utility of trunk groups, but may cause proliferate of congestion from a local to the whole network when traffic busy in a trunk group. The reason of this phenomenon occurred is due to that the traffic though alternative routes occupies more trunk groups than the direct route. When the traffic though an alternative route begins to compete circuits with the direct traffic, a positive feedback will cause these competitions more severely. So the trunks reservation strategy is put forward to avoid proliferate of congestion. The references [3], [8] and [12] give the research to the

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trunks reservation strategies, but lack of answer if having the optimum trunks reservation strategy and how it will be. This paper will answer the question by the theoretical and simulation methods.

2. TRUNKS RESERVATION ALGORITHM IN RTNR

In RTNR, there is a set of rules to determine the number of circuits reserved for the trunk group, but it needs the switches to monitor and calculate the following parameters:

C_k the number of direct calls in process for k^{th} OD (Origin and Destination switches) pair;

P_k the current call loss rate of direct calls for k^{th} OD pair;

A_k the current added traffic of direct calls for k^{th} OD pair, it is estimated by C_k and P_k which were got by the switch in last monitoring time;

V_k the number of circuits needed to satisfy the given QoS under A_k for k^{th} OD pair.

RTNR adopts a discrete threshold of reservations, R_k, it dependeds upon P_k and V_k, as shown in the table below [3]. According to the dynamic thresholds, the number of circuits reserved for the trunk group of k^{th} OD pair is as the following equation,

$$M_k = \min\{R_k, \max(0, V_k - C_k)\} \tag{2-1}$$

level of P_k	grade of reservations	threshold of reservations R_k
(0, 0.01)	0	0
(0.01, 0.05)	1	$0.05V_k$
(0.05, 0.15)	2	$0.10V_k$
(0.15, 0.5)	3	$0.15V_k$
(0.5, 1.0)	4	$0.20V_k$

3. THE SIMPLEX MODEL OF THE OPTIMUM RESERVATIONS

Due to the dynamic routing involving the traffic overflows, it is very difficult to get the precise analytic solution for circuits need in a trunk group of networks, not to say the optimum reservations. But we know that there should be an optimum reservation strategy to get a trade-off between the efficiency of network utility and the proliferation of network congestion. In order to get the optimum reservation strategy approximately, we establish a simplex network and several assumptions as follows.

(1) The simplex network consists of three nodes and three trunk groups with the same capacities (circuits or trunks) and the same added traffic, as shown in Figure 1. Let $\alpha_0 = \lambda_0/\mu$ be the direct (bi-direction) traffic to each trunk group, N be the number of circuits in each trunk group, and M be the number of circuits reserved for each trunk group.

(2) Each trunk group is a $M/M/N$ simple loss system, of which arrival calls are followed Poisson distribution with arrival rate λ_0, and the call duration followed exponential distribution with service rate μ.

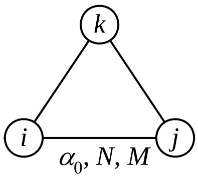

Figure 1 Simplex network

the orderliness of the optimum reservations M_0 with different α_0, N, M, as shown in Fig 3.

In Fig 3, the solid curves depict M-B_w relationship at given α_0, and we do find that there is the optimum reservation strategy as shown with dot curves.

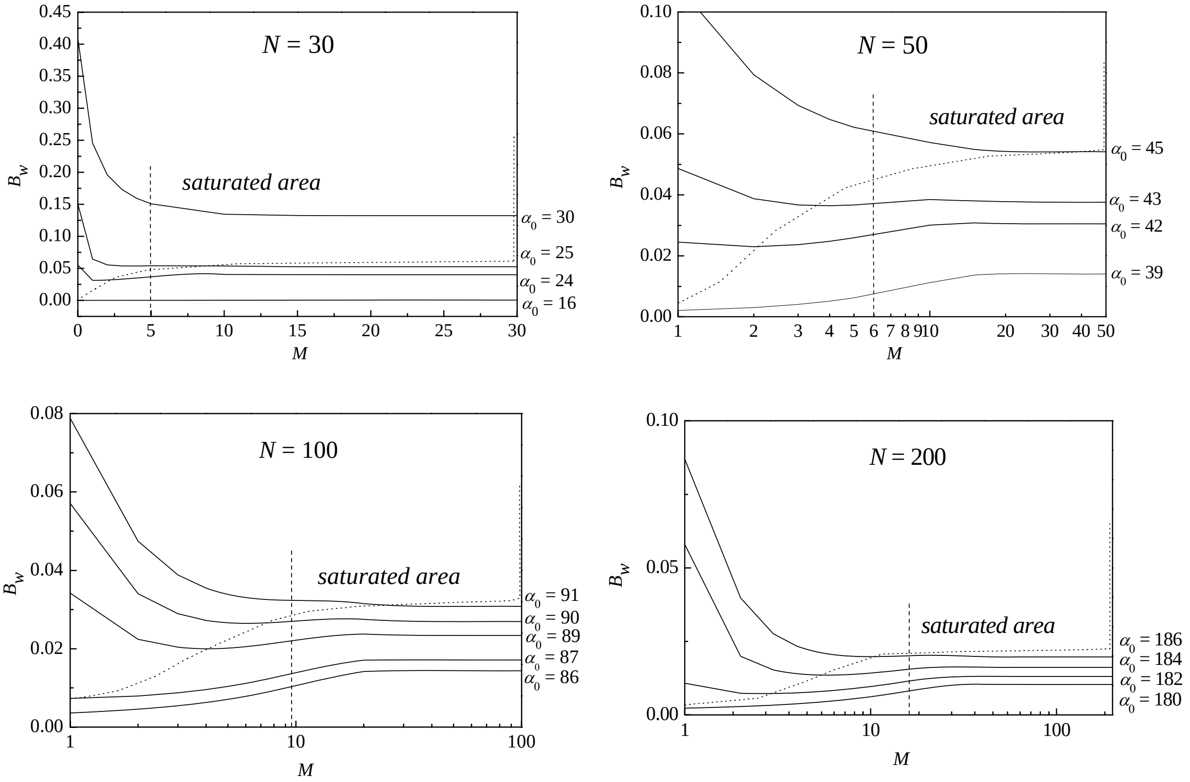

Figure 3 M-B_w curves and the optimum reservation strategy

From the observations in Figure 3, we can give the descriptions to the optimum reservation strategy:

1) With a relative lower α_0 to N, the curve M-B_w is increasing monotonously, so no trunks reservation is needed, that means alternative routes are opened freely.
2) With a relative higher α_0 to N, the curve M-B_w is decreasing monotonously, so all trunks are reserved, that means alternative routes are forbidden totally.
3) With a proper α_0 to N, the curve M-B_w has the minimum point at M_0, which is the optimum number of circuits reserved. The dot curve depicts the locus of M_0, which is something like the characteristics of the transistor, having a 'linear area' and a 'saturated area'. The boundary of 'linear area' of M_0 is generally less than 15 percentages of N, and the percentages becomes smaller with N increasing.
4) The larger the capacity N is, the smaller the B_w becomes, at which the curve M-B_w just begins decreasing monotonously.

4. THE ERROR ANALYSIS

It is turned out that there is the optimum reservation strategy by the simplex model that has some approximate assumptions. To verify the important fact, we use the call-by-call

regressions again, and obtain two linear functions for C_1 and C_2 as follows,

$$C_1 = 2.4394 - 0.3474N, \qquad C_2 = 1.8857 + 0.3868N \tag{5-2}$$

Table 5-1

The samples of N, α_0 and M_0 obtained from the simulations

$N = 30$			$N = 100$			$N = 200$			$N = 300$			$N = 400$		
α_0	M_0	α_0/N	α_0	M_0	α_0/N	α_0	M_0	α_0/N	α_0	M_0	α_0/N	α_0	M_0	α_0/N
21	0	0.700	80	1	0.80	170	1	0.85	255	1	0.850	345	1	0.863
22	1	0.733	81	1	0.81	172	2	0.86	260	1	0.867	350	1	0.875
23	1	0.767	82	1	0.82	176	3	0.88	265	2	0.883	355	2	0.888
24	2	0.800	83	2	0.83	180	4	0.90	270	3	0.900	360	3	0.900
25	2	0.833	84	2	0.84	182	5	0.91	275	5	0.917	365	4	0.913
26	3	0.867	85	2	0.85	186	6	0.93	280	7	0.933	370	6	0.925
27	3	0.900	86	3	0.86	188	7	0.94	285	9	0.950	375	7	0.938
28	3	0.933	87	3	0.87	190	8	0.95	290	11	0.967	380	9	0.950
29	4	0.967	88	3	0.88	192	9	0.96	295	14	0.983	385	12	0.963
30	5	1.00	89	4	0.89	194	10	0.97	300	17	1.000	390	14	0.975
			90	4	0.90	196	11	0.98	305	20	1.017	395	17	0.988
			95	6	0.95	198	13	0.99	310	20	1.033	400	20	1.000
			96	7	0.96	200	14	1.00				405	22	1.013
			98	8	0.98	202	15	1.01				410	26	1.025
			99	9	0.99	204	16	1.02				415	28	1.038
			103	10	1.03	206	16	1.03				420	28	1.050
						208	17	1.04						
						210	18	1.05						
						212	20	1.06						

Table 5-2

Regression coefficients C_1, C_2 with N

N	C_1	C_2	R^2*	*prbo. of F*
30	-9.10655	13.86085	0.948	<0.0001
50	-13.9176	19.89620	0.984	<0.0001
100	-31.3424	40.11426	0.996	<0.0001
200	-72.6389	85.89856	0.997	<0.0001
250	-80.0228	94.35498	0.992	<0.0001
300	-99.4703	115.5359	0.992	<0.0001
400	-138.502	157.9316	0.992	<0.0001

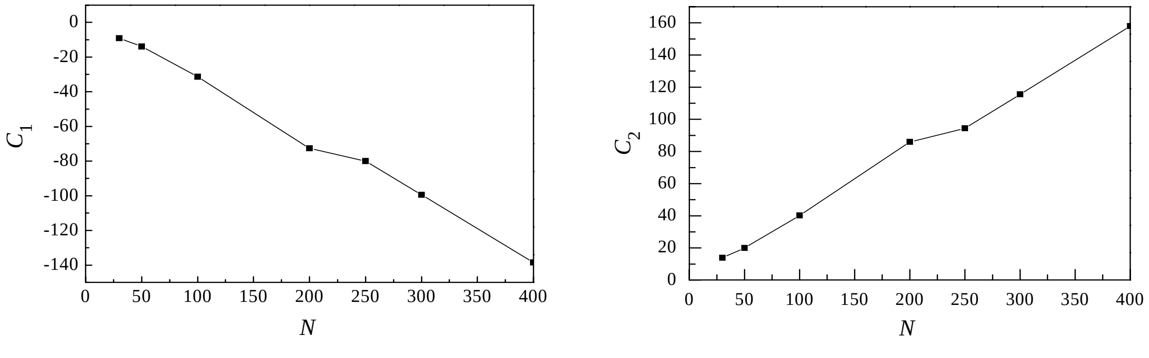

Figure 5 The scatter diagrams of C_1-N and C_2-N

6. GENERAL NETWORK SIMULATIONS AND RESULTS COMPARISON

The basic parameters for simulating are: μ =18 calls per hour, the system warm-up time or transition time for simulating is 3600 seconds, the simulating time at the steady-state of the system is 14400 seconds, and the interval of monitoring and making statistics on-line by the switches is 180 seconds. The other network parameters for some test networks are shown in Table 6-1, 6-2 and 6-3, in which the up-triangle of arrays contains the direct call arrival rate λ_{ij} and the low-triangle contains capacity of trunk group N_{ij}. The test networks II to VI have the same N_{ij} as network I, but with larger and larger λ_{ij}. The simulated results are shown in the Table 6-4.

Table 6-1
The parameters of network I

Direct call arrival rate λ_{ij} unit: calls per hour

Capacity of trunk group, N_{ij}

	1802	1446	2714	1632	3253	1093	1260
117		731	1446	731	1802	554	731
96	53		2162	1093	2162	554	731
170	96	138		1446	2714	1093	1446
107	53	75	96		2162	554	1093
201	117	138	170	138		911	1446
75	42	42	75	42	64		1632
85	53	53	96	75	96	107	

Table 6-2
The parameters of network VII

Direct call arrival rate λ_{ij} unit: calls per hour

Capacity of trunk group, N_{ij}

	6061	4927	8937	5521	10625	3797	4335
351		2622	4927	2622	6061	2039	2622
288	159		7199	3797	7199	2039	2622
510	288	414		4927	8937	3797	4927
321	159	225	288		7199	2039	3797
603	351	414	510	414		3208	4927
225	126	126	225	126	192		5521
255	159	159	288	225	288	321	

Table 6-3
The parameters of network VIII

Direct call arrival rate λ λ_{ij} unit: calls per hour

Capacity of trunk group, N_{ij}

	12424	10135	18218	11333	21613	7850	8937
702		5467	10135	5467	12424	4281	5467
576	318		14718	7850	14718	4281	5467
1020	576	828		10135	18218	7850	10135
642	318	450	576		14718	4281	7850
1206	702	828	1020	828		6657	10135
450	252	252	450	252	384		11333
510	318	318	576	450	576	642	

obtained at the same networks and traffics. One reason we guess is that the average duration (half hour) of Internet services is too longer than that of the telephone call, one internet service session witch occupying an alternative route may cause a lot of losses to the telephone services. So it is obvious that the telephone service should have an independent bandwidth separated from the Internet services, even for IP telephone service, to guaranty the quality of voice and a lower loss rate.

We believe that the optimum reservation strategy for the dynamic routing is an essential characteristic whatever for circuit-switched network or packet-switched network. Routing in IP networks is dynamic at its born, and the structure of IP networks is sparser than that of telephony, something like our simplex networks, so our research results especially the research methodology are significant to the research of routing algorithms on NGN or NGI.

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