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COMPUTER ALGORITHM FOR PERFORMANCE EVALUATION OF PACKET SWITCHING COMPUTER NETWORK

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Abstract: - Most distributed computer systems make use of packet-switching techniques where the packets flow through the system in a store and forward manner. Many packets of some message may be transmitted simultaneously thus reducing transmission delay. In such systems, computer resources are distributed among the system and the computers are interconnected together through communication sub-network. This paper offers a computer algorithm for calculating performance indices for computer network giving better insight to the network performance and allowing assessing the impact of network parameters on its performance .The algorithm is tested, and the result of computation for one case study is included.

Keywords: packet-switching, communication sub-network, Delay

Introduction

In packet switching technique, many packets of the same message may be transmitted simultaneously, at each intermediate node a table look-up is made which yields the address of the link next on the packet's route, and at the destination the packets is reassembled and routed to the receiving process. Routes are defined by entries in node's routing table [1]. A node handles all communication requirements, such as handshaking, routing, error free and flow control. A node has a processor, a buffer for storing the packets and line equipment. Measures and evaluation of performance for such system become very important, allow improving system, and giving system planner better insist into system performance [2]. The performance of a packet switching sub network is mainly characterized by the following variables:

- Network delay: The time between a packet entrance to communication
- Sub network from the source host and exit to the destination host.
- Throughput: The number of packets that the entire communication subnet work service per unit time (service rate).
- Utilization: The preparation of time the node is busy.
- Queue length: Number of packets at the node (both waiting and receiving service)[3].

Mean value analysis technique

In analysis, the packet switching distributed computer network can be modeled as closed queuing network [4].

Notations

N : Number of nodes in the communication sub-network.
NP : Number of packets in the communication sub-network.
X(NP) : Throughput in packets per unit time of the sub network with load NP.
R(NP) : Network delay with load NP.
nk(NP) : Queue length of node K.
Sik : Service time of node K.
RK(NP) : Mean response time of node K.

Equations

- Queuing network as a whole: $X(NP) = \frac{NP}{\sum_1^N RK}$ (1)

- For each node: NK(NP) = X(NP) * RK(NP) (2)

- The mean response time of node K :

$$RK(NP) = \begin{cases} SIK & delay\ node \\ SIk * \left(1 + NK(NP-1)\right) & queuing\ delay \end{cases} \quad (3)$$

Note that, at the moment a packet NP arrives at sub network, it is certain that this packet itself is not already in queue there [5]. Thus there is only N-1 other packets that could be possibly interfering with new arrival. Using equations (1), (2), (3), the throughput, delay of sub network can be computed, and queue length for each node [6].

Since the time averaged queue lengths with one packet in the sub network is equal to the arrival instant queues lengths with two packets in the sub network, the solution obtained for one packet can be used to compute the solution with a two packets [7]. Successive application of the equations compute solutions for 3, 4, 5 ,… , NP-1, NP packets as follows:

Initialization

NK(0) = 0 K = 1, 2, … , N

For M = 1 to NP

Begin

RK(M) = SK + SK * (1 + NK(M-1))

R(M) = $\sum_1^N RK(M)$

$X(M) = M / R(M)$

$NK(M) = X(M) * RK(M) \qquad K = 1, 2, \ldots, N$

End

Performance Model

The model to be formulated is based on the following assumptions:

1- Fixed routing table.
2- The sub network operates in a store-and-forward manner.
3- The queuing discipline at each node is first-come-first serviced (FCFS).
4- Each ode contains only one processor to perform communications.
5- Applying stochastic queuing theory.
6- All nodes and links are reliable.

Note that, in packet switching distributed computer network, two distinct types of components identified as follows:

- Host computer.
- Packet switching sub network.

The hosts are numbered 1' though N' and nodes are numbered 1 through N. The host K' is connected to node K.

There are three data structure used here:

1- The fixed routing table, which specify the path between pair of hosts R(1', J'); i = 1' , 2', … N'; J = 1', 2', …, N'; i' ≠ j' .
2- Destination probability table specifying for each i', j' pair (p(i', j')), probability that a packet generated by the host i' will be ultimately destined for host j'.
3- Service time table, which specify the service of the node K when a packet is to be transmitted to its neighbor L (node/host which has direct connection to node K), assume set of neighbor of node K are N1, N2, …, NLK.

A packet after getting service at a node may either leave the subnet work to a host or make transaction to one of its neighbor nodes, so the transaction probabilities are calculated from routing and destination probability tables.

Some additional notations:

M	: Number of packets delivered by the hosts into the communication subnet work during time interval T.
B(K)	: Set of neighbors to node K.
M(i', j')	: Number of packets going from i' to j' during T and are carried by route R(i', j').
fK	: fK = MK/M, the percentage of total packets serviced by the ode K.
PT(K,I)	: The transaction probability of packets going from node K to its neighbor I, PT(K,I) = MKI/MK.
UKI(NP)	: Utilization of node K due to packets flowing from node K to its neighbor I when the subnet work load is NP.
XOK(NP)	: Output rate of node K when the load of subnet work is NP.
XOKI(NP)	: Rate of packets flow from node K to its neighbor I.
RKI(NP)	: Response time of node K for a packet going from K to I.
SLKi	: Mean service Time of Node K when a packet is to be transmitted to its neighbor I.

The Algorithm

The following algorithm calculates the performance indices.

Step 1

Input the number of hosts, N, the number of nodes in the sub network and the routing table R (i', j'), i' = 1', 2', …, N', j' = 1', 2', …, N', i' ≠ j' .

Calculate the fraction of total packets processed by any node fK (K = 1, 2, …, N) as follows:

- Assume P(i', j') is constant for all i' = 1', 2', …, N'; j' = 1', 2', …,N'; i' ≠ j'. The total number of route entries = N ** 2 - N.

- If the total number of packets processed by sub network is N ** 2 - N, then the total number of packets processes by node K are:

$$MK = \sum_{L=1}^{N**2-N} K \ , K \epsilon R(i', j')$$

fK = MK / (N**2-N)

Calculating, the transaction probabilities PT(K,I) from routing table.

- Assume MKI are the number of packets going to neighbor I after processing in node K, then:

PT (K, I) = MKI / MK

$$MKI = \sum_{L=1}^{N**2-N} KI \ , KI \epsilon R(i', j')$$

$$PT(K, I) = \sum_{L=1}^{N**2-N} KI \Big/ \sum_{L=1}^{N**3-N} K$$

Step 2

Input the service time table SKI, K = 1, 2 , … N; I = N1, N2, …, NLK.

Step 3

Input the number of packets in the sub network NP. Calculate performance indices as follows:

1- Initialization

nk(0) = 0 K = 1, 2, …, N

2- For M = 1 to NP

Begin

$RK(M) = \sum_I SLKI * PT(K,I) * [nk(m-1)+1]$

$R(M) = \sum_{K=1}^{N} fK * RK(M)$

$X(M) = M/\ R(M)$

$nk(M) = fK * X(M) * RK(M)$ $\quad K = 1, 2, \ldots, N$

$XOKI(M) = PT(K,I) * fK * X(M)$

$UKI(M) = XOKI(M) * SLKI$

$UK(M) = \sum_I UKI(M)$ $\quad K = 1, 2, \ldots, N$

End

Note that to change service time go to step2, to change routing table to step 1 and skip step2, to change routing table and service times go to step 1 .

Case study

The algorithm is used to calculate the performance indices in the Cyclades network shown in following figure:

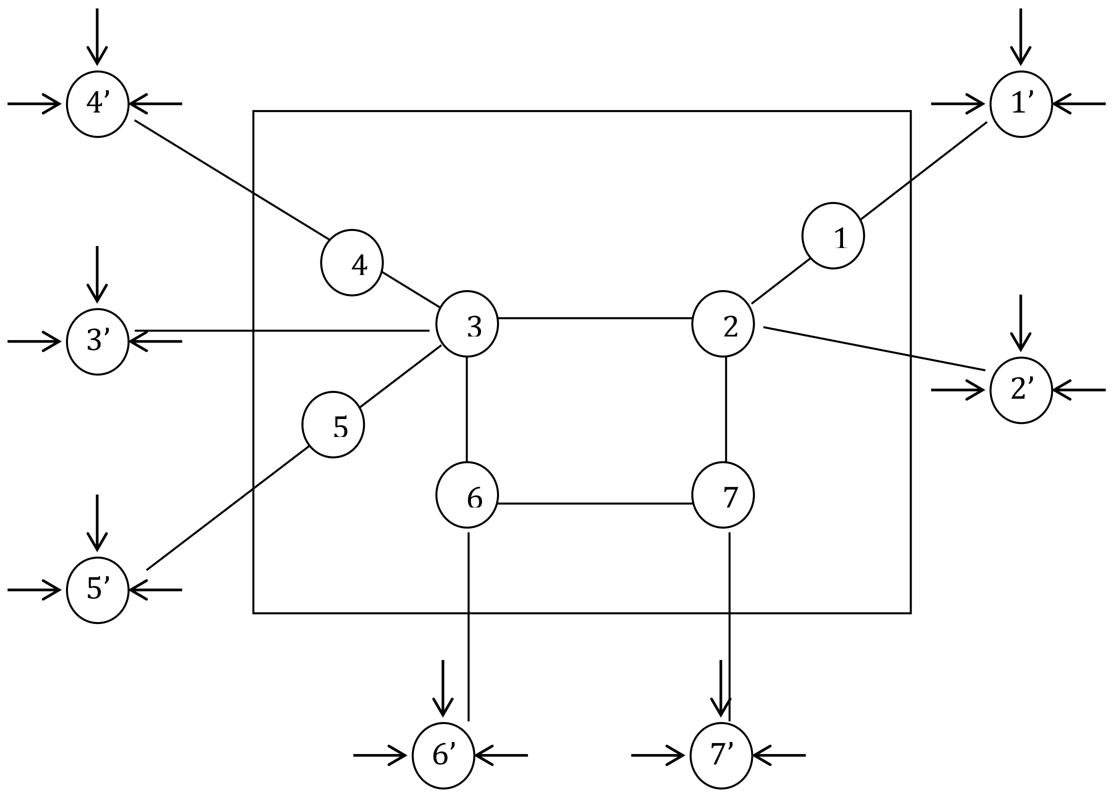

Fig. (1) Calculation the performance indices in the Cyclades network

The steps of the algorithm are implemented In FORTRAN. The fixed routing table is changed (R1, R2, R3, R4) and the service times are changed, SLKI starts with 0.10 and increases with 0.10 till S1KI = 0.30.

Results

Sample of the results are included in table 1, 2, 3 and figure 1, 2, 3, 4, 5, 6.

From these results, the performance measures i.e. throughput, delay, queue length and utilization are affected by network parameters (packet load, service time, fixed routing table) as follows:

Throughput:

The throughput increase as the packet load increases until it reaches the saturation value at which the throughput will remain constant if the packet load increases over.

Delay:

- The delay decreases as the service time decreases.
- It increases as the packet load increases.
- It is affected by the fixed routing table chosen.

Queue lengths:

- The queue length at each node increases as the packet load increases.
- They are affected by fixed routing table chosen.

Utilization:

- The utilization of nodes increase as the packet load increases.
- They are affected by the fixed routing table chosen.

Table (1) Sample of Throughput and Delay at service time

No. of packets	Throughput at service time			Delay at service time		
	0.1	0.2	0.3	0.1	0.2	0.3
4	9.7	4.9	3.3	0.5	0.9	1.3
8	12.6	6.5	4.1	0.8	1.2	1.9
12	13.7	6.9	4.5	1.0	1.7	2.7
16	14.1	7.1	4.6	1.3	2.2	3.5
20	14.3	7.2	4.7	1.5	2.7	4.2
24	14.3	7.2	4.7	1.8	3.2	5.1
28	14.3	7.2	4.7	2.0	3.7	6.0
32	14.3	7.2	4.7	2.3	4.3	6.9
36	14.3	7.2	4.7	2.6	5.0	7.7
40	14.3	7.2	4.7	2.8	5.5	8.5
44	14.3	7.2	4.7	3.1	6.2	9.3
48	14.3	7.2	4.7	3.3	6.9	10.0

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Table (2) Sample of Queue lengths and Utilization at nods

No. of packets	Queue lengths at nodes				Utilization at nodes			
	1,4,5,7	2	3	6	1,4,5,7	2	3	6
4	1	1	3	1	0.28	0.5	0.68	0.41
8	2	4	6	3	0.36	0.65	0.9	0.53
12	2	6	7	4	0.39	0.7	0.96	0.59
16	2	6	10	4	0.4	0.72	0.98	0.59
20	2	6	13	4	0.4	0.72	0.98	0.59
24	2	6	17	4	0.4	0.72	0.98	0.59
28	2	6	21	4	0.4	0.72	0.98	0.59
32	2	6	25	4	0.4	0.72	0.98	0.59
36	2	6	28	4	0.4	0.72	0.98	0.59
40	2	6	32	4	0.4	0.72	0.98	0.59
44	2	6	36	4	0.4	0.72	0.98	0.59
48	2	6	40	4	0.4	0.72	0.98	0.59

Table (3) Sample of Throughput and Delay at Route

No. of packets	Throughput at Route			Delay at Route	
	R1	R2	R3, R4	R1,R3, R4	R2
4	4.5	4.5	4.5	0.8	0.8
8	6.1	6.5	5.9	1.3	1.1
12	6.6	7.1	6.5	1.6	1.5
16	7.1	7.6	6.9	2.1	1.8
20	7.1	7.7	7.0	2.6	2.3
24	7.1	7.8	7.0	3.3	2.9
28	7.1	8.0	7.0	3.9	3.4
32	7.1	8.0	7.0	4.2	3.9
36	7.1	8.0	7.0	5.1	4.4
40	7.1	8.0	7.0	5.8	5.0
44	7.1	8.0	7.0	6.2	5.2
48	7.1	8.0	7.0	7.0	5.8

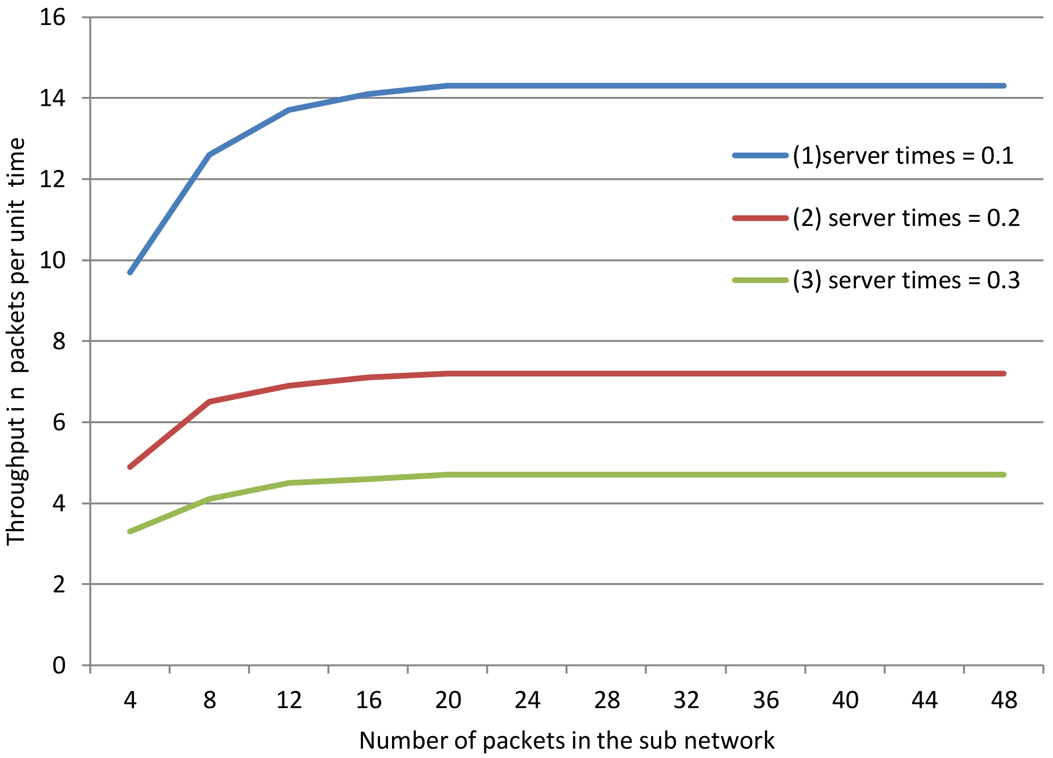

Fig. (2) Result of Throughput at service time with number of packets

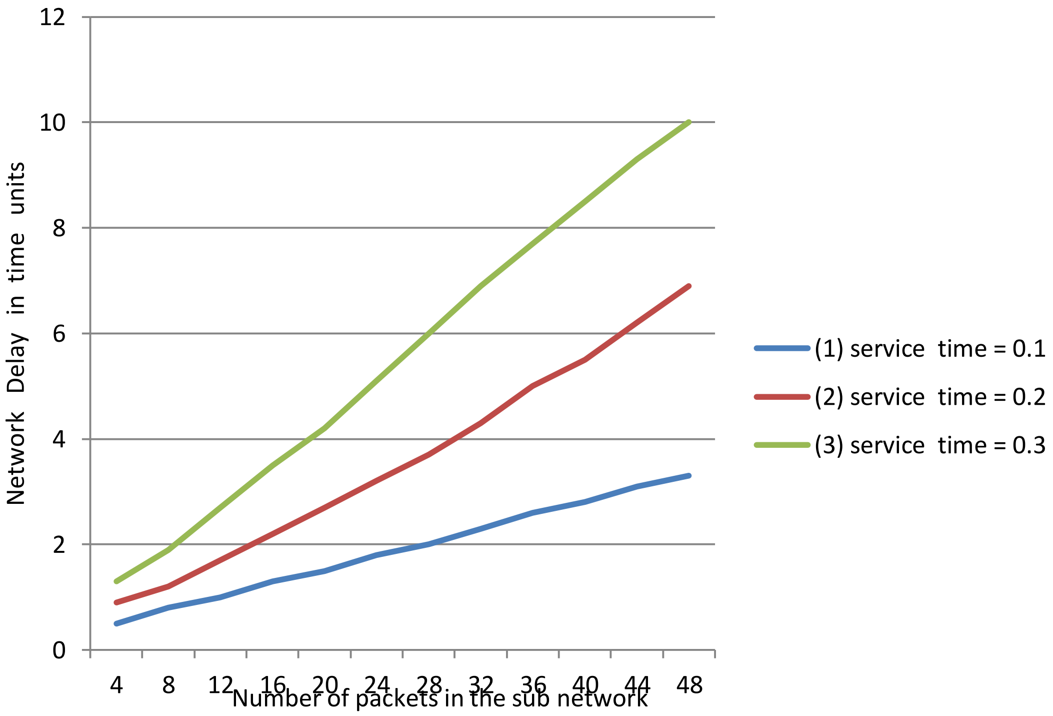

Fig (3) Result of Delay at service time with number of packets

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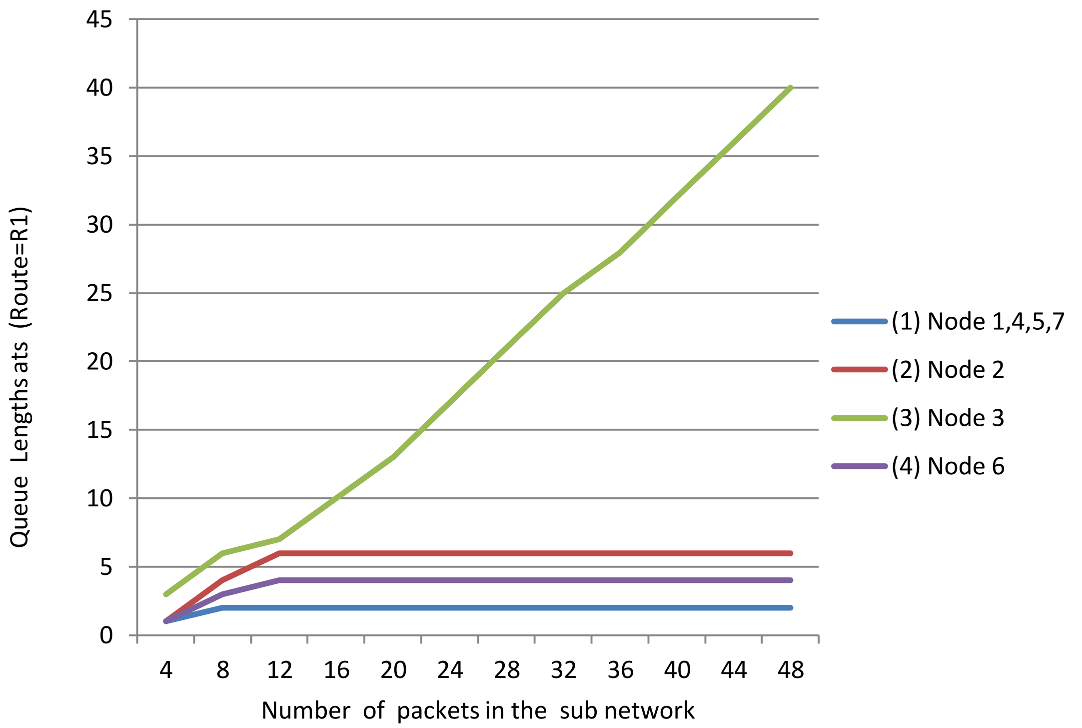

Fig(4)Result of Queue Lenghths with number of packets

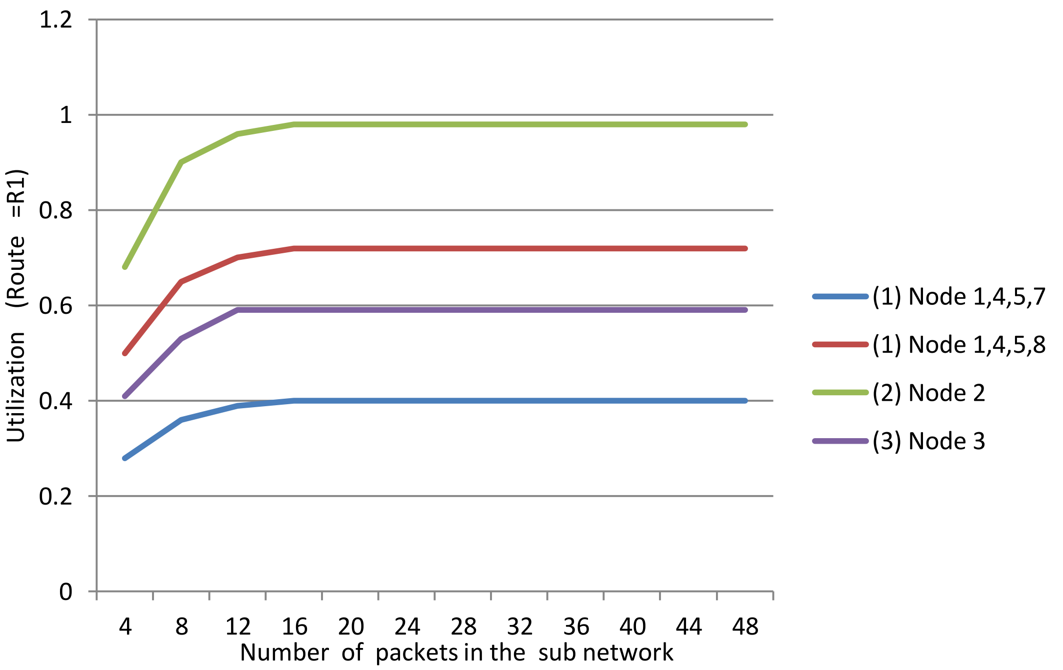

Fig. (5) Result of Utilization with number of packets

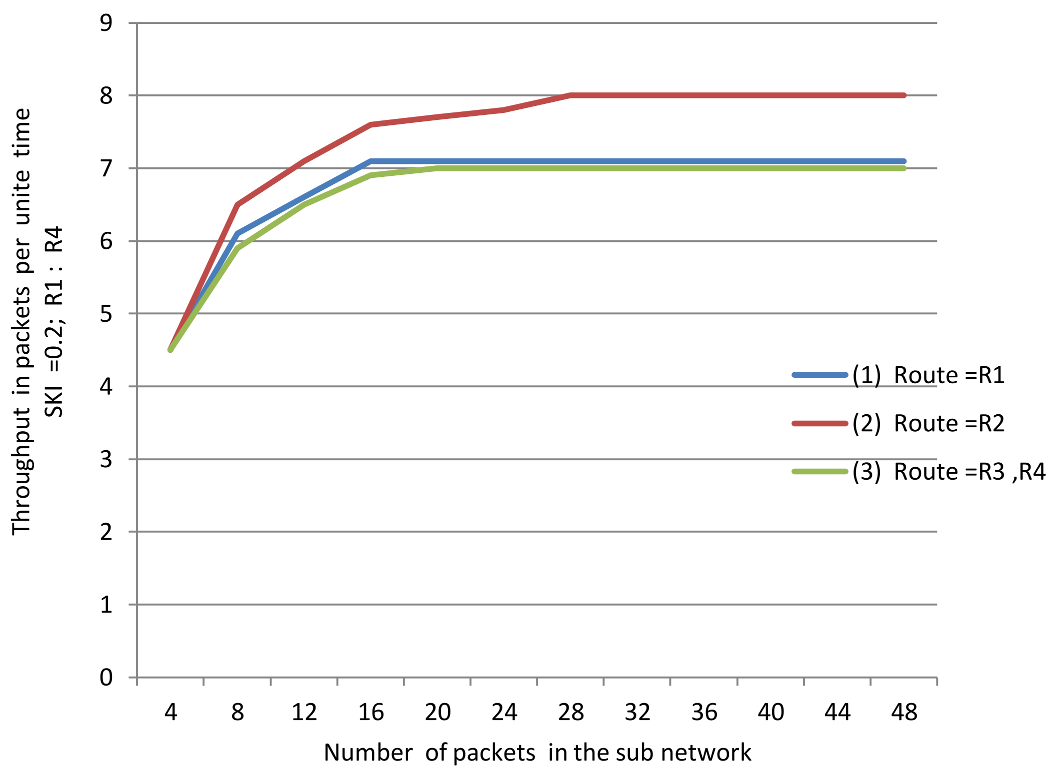

Fig . (6) Result of Throughput at Route with number of packets

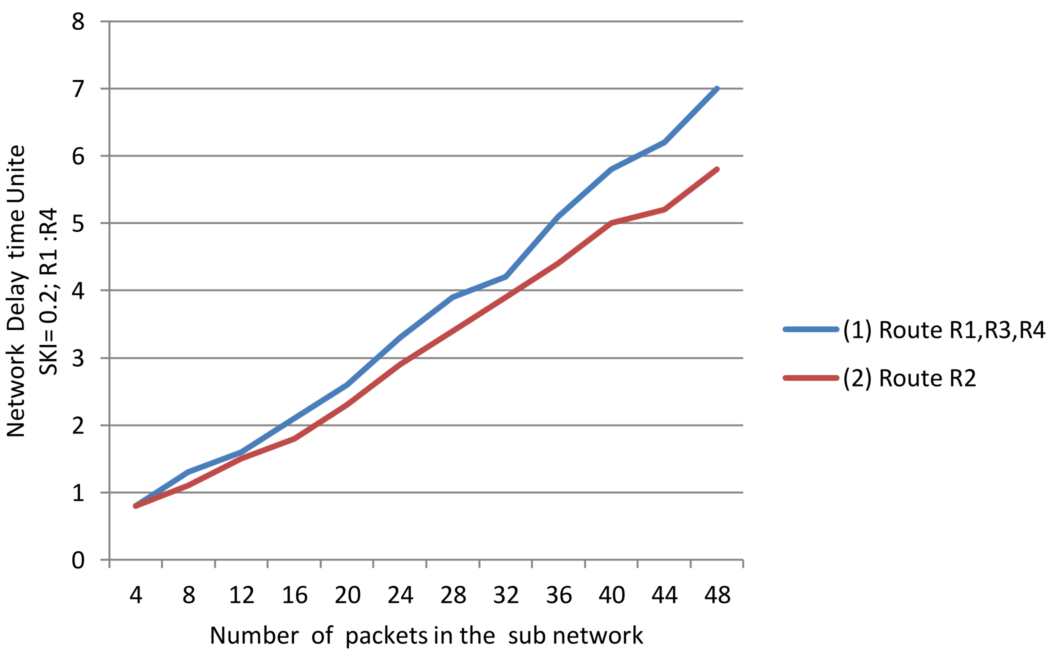

Fig.(7) Result Delay at Route with number of packets

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Conclusion

System performance can be improved From the iterative steps of the algorithm as follows:

The solution of throughput to control the flow of packets into the sub network can be known. The queue length of each node is known , hence a buffer size required to it can be assigned. Utilization of each node can be computed to increase or decrease processing of it. The average network delay can be calculated to know the expected response time. By changing the sub network parameters such as fixed routing table and service time, and calculating the performance ideas, the best fixed routing table and service time can be chosen for specified requirement (throughput, response time, … etc.).

These points allow improving system behavior and giving system planner better insight into system performance.

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