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A Framework for Upgradation of Network Link Bandwidth to Network Service Provider

P. Ganesh Kumar and K. Thyagarajah
Department of IT, PSNA College of Engineering and Technology Dindigul, Tamilnadu, India

Abstract: The network size is evolving rapidly now-a-days and there is a need to provide high degree of Quality of Service (QOS) to the users. In this study the technique of optimal routing is used to determine the best business decision for link capacity upgradation . Business decision is used to find out the time beyond which the existing network link capacity will not provide the required level of QOS to users and the time by which capacity of link should be upgraded. This helps to increase the revenue and also to maintain the optimal QOS that the users trust on the network. Before admitting a flow of data its flow specification must be checked and it must be optimally routed. Delay is an element which has to be reduced to provide better QOS. To reduce this delay, the link utilization has to be decreased. Link utilization is defined as the ratio between total flow demand and link capacity. This can be achieved by limiting the flow of data in the corresponding link, through increase in cost of the link. We propose a new methodology to identify the optimal time period for deploying network devices for link bandwidth upgradation. This is achieved through optimal routing technique by identification and cycle deduction.

Key words: Framework, upgradation of network, link bandwidth, network service provider, QOS

INTRODUCTION

It is expected that many future communication networks will integrate diverse services such as voice, multimedia and data with appropriate quality. To enable such multiservice network architecture various mechanisms and methodologies have been developed, which introduced the idea of Quality of Service (QOS) into the network and which promotes efficient and proper use of the available resources. To guarantee network wide end to end QOS to data flows proper capacity planning, expansion of capacity and optimal use of resources are required.For designing adequate quality of service provision, capacity planning ,it is critical to understand the traffic characteristics. There are literatures characterizing traffic in wired and wireless networks (Mark and Azer, 1996; Leland *et al*., 1995, 1994; Willinger *et al*., 1995). Network planning engineer job is to have definitive market research on the amount of bandwidth that user will require in 2,5 and 10 years. Researchers have to translate market application scenarios into concrete network requirement projection. It is complex to do so because of the many interdependencies of the software and hardware applications as well as policies and practices within the business itself. These complexities must then be set against the quickly realm of network technologies and thus the researchers must be an expert in both the market segment and network technologies. It is well known that the network traffic has a cyclic behavior with 24 h cycle. In terms of bandwidth provisioning an extreme case will be to consider the maximum traffic in a 24 h period and determines the bandwidth needed based on this maximum traffic estimate. A new technique has been derived to understand the daily, weekly and monthly demand profile of system overtime in (Capacitas limited, 2006). From the literature, it can be seen that more work have been devoted to traffic forecasting and capacity planning when the network is in operation. After forecasting the future traffic, the capacity needed for future say after in 2,5 and 10 years can be determined. After finding out the future link capacity required, proper business decision should be made so as when the forecasted link capacity should be clubbed with the existing network. Thus the technical team and the management team should go hand in hand to minimize the cost without compromising on QOS. It is hypercritical to identify the time of upgradation (i.e., upgradation before demand will result in loss of capital investment on the other hand getting late means loss of customer will). In this study we investigate the network

Corresponding Author: P. Ganesh kumar, Department of IT, PSNA College of Engineering and Technology Dindigul, Tamilnadu, India

link capacity expansion process from the basis of optimal routing (Berry *et al*., 2000; Staehle *et al*., 2000). First, the procedure of optimal routing is performed by using the available link capacity. The goal is to identify the "cycle" occurring between two links. And ultimately it gives a clear picture about the time for upgradation which makes the best business choice.

Background: With the advancement of network technology more business,people and devices are connected which results in rapid rise of data. At the same time, more and more businesses are involved in using network. The degradation of network performance must be identified at the earlier stage and should be rectified by enhancing the capacity of the network to provide better QOS.

QOS can be defined in several parameters. Those parameters can be used for evaluating different networks. Delay is the time taken by the packet to reach from source to destination. Jitter is the variation in delay for packets belonging to the same flow. The range of frequencies that the medium can pass without losing one-half of the power is called as the bandwidth. All the values of the parameters can be optimized if link utilization is kept in an optimal level(minimum level).

It will be useful for the network service providers to provide better QOS to their customers. To provide better QOS, link utilization should be decreased.

The study helps to determine whether the network will be able to provide better QOS when the flow in the link increases. In the proposed technique, first the flow in the link is reduced by optimal routing(optimal routing is done by examining the utilization of the link capacity and if it is larger, then it is reduced by increasing the cost of the link). But in optimal routing there is chance for a series of link to get maximum utilization again and again. This is termed as cycle formation.

The cycle formation is an indication that the flow cannot redirected to other links further to provide better QOS. The solution is to adopt capacity planning by enhancing the capacity of the link which will help the network service providers to provide QOS to their customers.

A SIMPLE DESIGN EXAMPLE

Many source destinations (egress-ingress)traffic demands between various points (nodes) in the network are available which needs to be estimated, forecasted or determined by other means such as marketing. Thus traffic/demand matrix is input to the network design. Then network with enough capacity and connectivity need to be determined to route this traffic so that acceptable service guarantees can be provided.

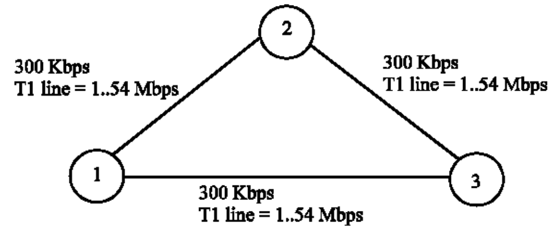

Fig. 1: Three node example with three links installed

If the traffic between two points are known , then by using an acceptable link utilization threshold ,link capacity can be determined. This principle is used in this study as formula to link bandwidth up gradation. To address the role of network design, a three node network where the traffic demand between each node is on average 300Kbps is considered (Fig. 1). For quality of service requirements, if it is required to maintain a utilization threshold of no more than 60% for any link and if it is allowed to use links of T1 capacity unit size (T1= 1.54 Mbps),the intuitive answer could be to put three T1 links, one between each pair of nodes to satisfy the demand and the utilization requirement. In this case, the link utilization, is 300 Kbps/ 1.54 Mbps = 19.5% which is below the acceptable threshold, therefore service guarantee is met.

DESCRIPTION

Network planning engineer job is to have definitive market research on the amount of bandwidth that users will require in 2, 5 and 10 years. After predicting the amount of bandwidth required for the future the network engineer should properly identify the correct time at which the bandwidth of the system or link should be enhanced. This study illustrates a technique which is used to find the time at which the link bandwidth should be increased. This technique is based on optimal routing. First optimal routing is done, with the help of this optimal routing maximum link utilization is reduced for the link which is having the maximum link utilization. This procedure is repeated until cycle is determined. Determination of cycle indicates that the link capacity of the link in which cycle is determined must be enhanced.

Algorithm:

- Let the number of nodes be N such that N = {1,2,….N} is obtained from the user.

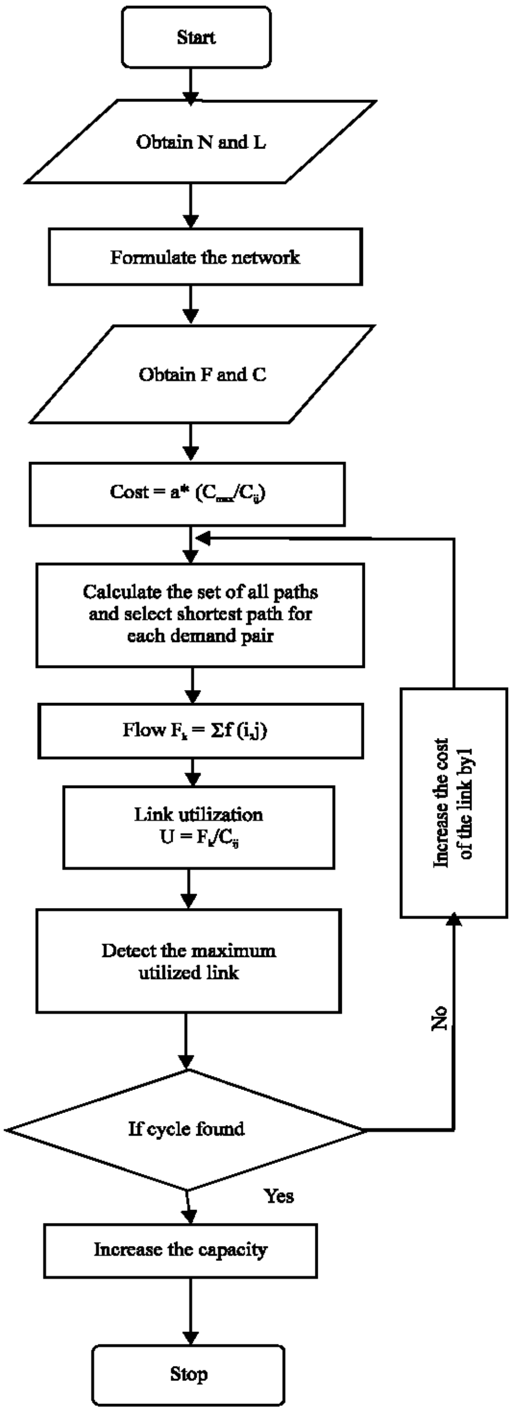

Fig. 2: Flow chart

- Let the links (L) that exists between different nodes are got from the user.
- Formulate the topology G= (V, E) where V= {1, 2…N} and E = {e_1, e_2, e_3 …L)
- Let the flow demand be F and link capacity be C.
- The value of F is obtained from the daily workload profile of the demand pair
- The value of C is the original capacity of the links. Cost of each link is calculated by using the formula

$$P = a^*(C_{max} / C_{ij})$$

Such that C_{max} = Maximum link capacity, C_{ij} = Link capacity of the link i,j.

- Set of all paths between each demand pair is found out.
- The Shortest path for demand pair i,j from the existing set of all paths is found out f(i,j).
- Flow in each link is calculated by $F = \sum f(i, j)$.
- Link Utilization is found using the formula U = (F/C).
- The Link with maximum utilization is identified and the cost of the link with maximum utilization is incremented by 1.
- Step 6-10 is repeated to detect cycle.

Flow chart: Figure 2 shows flow chart which represents the procedure in step by step manner.

The proposed technique consists of the ollowing modules:

- Network formulation.
- Flow demand estimation from daily workload profile.
- Link cost calculation.
- Shortest path detection.
- Link utilization calculation.
- Cycle detection.
- Enhancing the capacity of the link.

Network formulation: The network formulation module is mainly used to formulate the network topology from the data obtained from the user about the network. The Steps involved in this module are:

- Obtain the number of nodes present in the network.
- Obtain the details about the links which exists between the nodes.
- Obtain flow demand values for each demand pair.

The demand pair is set of nodes; the flow value represents the traffic at peak time. The flow demand value can be measured by using specific tools such as Net Flow.

- Obtain the link capacity values.

Using the above information the network topology is formulated.

Example: Number of nodes = 6

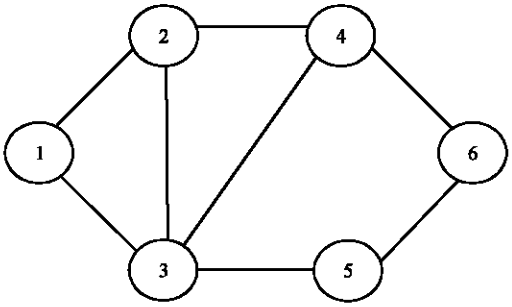

Fig. 3. Topological structure

Table 1: Flow demand matrix

Links	1	2	3	4	5	6
1	0	8	5	12	3	7
2	8	0	2	11	9	14
3	5	2	0	3	7	6
4	12	11	3	0	4	1
5	3	9	7	4	0	3
6	7	14	6	1	3	0

Table 2: Link capacity matrix

Links	1	2	3	4	5	6
1	0	30	40			
2	30	0	60	20		
3	40	60	0	10	30	
4		20	10	0		
5			30		0	60
6				40	60	0

Link exists between nodes (1,2), (1,3), (2,3), (2,4), (3,5), (3,4), (4,6), (5,6). The topology of the example network is shown in the Fig. 3.

Flow demand matrix and link capacity matrix are the input which are obtained from user. The data's used in the example are given in the Table 1 and 2.

Link cost calculation: This module mainly focuses on calculating the link cost for each link (Fig. 4).

The link Cost is calculated using the formula

$$Cost = a*(C_{max} / C_{ij})$$

Where a = constant (10),C_{max} = Maximum capacity value in the link capacity matrix and C_{ij} = Capacity of the link which exists between the nodes i and j.

Example:

For Link (1,2) Cost = (10*60)/30 =20
For Link (1,3) Cost = (10*60)/40 =15
For Link (2,3) Cost = (10*60)/60 =10
For Link (2,4) Cost = (10*60)/20 =30
For Link (3,4) Cost = (10*60)/10 =60
For Link (3,5) Cost = (10*60)/30 =20
For Link (4,5) Cost = (10*60)/40 =15
For Link (5,6) Cost = (10*60)/60 =10

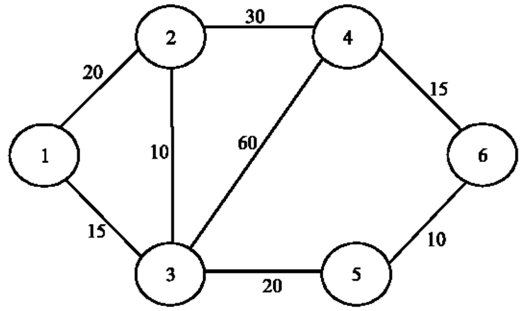

Fig. 4: Network with link cost

Table 3: Link utilization calculation

Link	Flow	Capacity	Utilization
(1, 2)	20	30	0.666
(1, 3)	15	40	0.375
(2, 3)	28	60	0.46
(2, 4)	26	20	1.3
(3, 4)	0	10	0
(3, 5)	46	30	1.53
(4, 6)	5	40	0.125
(5, 6)	34	60	0.56

Link utilization calculation: Link Utilization is the ratio between the total flow demand in a particular link and capacity of the link.Link Utilization = Total Flow Demand/ Link Capacity For the network in the link utilization for the link (1, 2) can be determined as follows.Total Flow Demand = Flow Demand (1, 2) +Flow Demand (1, 4) = 8+12 = 20. Link Utilization = 20/30 = 0.666.The link utilization of all the links of the example network is given in Table 3.

The maximum utilized link is (3, 5). The link utilization value is 1.53.

Cycle detection: After calculating the maximum utilized link, the cost of that link is incremented by 1. The steps involved are: The new shortest paths for all the demand pair is calculated. The change in the flow value is tabulated for each link and link utilization is calculated. The above step is repeated after each iteration by incrementing the cost of the link by 1 for the link which is having maximum utilization.After 7th iteration the change in flow and link utilization for each link is listed in Table 4. The figure shows that the maximum utilized link is (2,4). After 9th iteration the change in flow and link utilization for each link is listed in Table 5. The figure shows that the maximum utilized link is (3,5). From the above it is observed that links (3, 5) and (2, 4) are getting maximum utilization. It indicates the formation of cycle between the links (3, 5) and (2, 4). Cycle Formation is an indication that further the flow cannot be decreased in the link to obtain lower link utilization. For better QOS link should have lower utilization.utilisation is the ratio of flow to capacity. To decrease the link utilization either flow can be reduced or capacity can be increased but from the above itis concluded that flow cannot be further reduced because of the occurrence of the cycle between the links (3,5) and (2,4). Therefore to provide higher QOS the link capacity of the links (3,5) and (2,4) should be increased.

IMPLEMENTATION

All the modules are implemented in MATLAB version 7. The sequence diagram (Fig. 5) shows the interaction of different modules in the system.

The input and output of the implemented system is given.

Table 4: Link utilization calculation after 7th iteration

Link	Flow	Capacity	Utilization
(1, 2)	20	30	0.666
(1, 3)	15	40	0.375
(2, 3)	14	60	0.23
(2, 4)	40	20	2
(3, 4)	0	10	0
(3, 5)	32	30	1.06
(4, 6)	19	40	0.475
(5, 6)	20	60	0.333

Table 5: Link utilization calculation after 9th iteration

Link	Flow	Capacity	Utilization
1-2	20	30	0.666
1-3	15	40	0.375
2-3	28	60	0.466
2-4	36	20	1.3
3-4	0	10	0
3-5	46	30	1.53
4-6	5	40	0.125
5-6	27	60	0.45

First module

Network formulation: This module is used to formulate the network.The number of nodes and the connection among them is got as input.

Example: Number of nodes = 6.Connection exists between the following nodes1 and 2, 1 and 3, 1 and 4, 1 and 5, 1 and 6, 2 and 3, 2 and 4, 2 and 5, 3 and 4, 3 and 5, 3 and 6, 3 and 5, 4 and 6, 5 and 6.

The snapshot of the network formulation is shown in the Fig. 6.

Second module

Link cost calculation: This module is used to calculate the cost for each existing links

Input: Table 6 shows the input.

Output: Table 7 shows the output.

Third module

Shortest path detection: In this module all possible paths for each demand pair are detected. Path with minimum cost is selected as shortest path.

Shortest Path for each demand pair is given in Table 8.

Fourth module

Link utilization calculation: Link Utilization is calculated for each link using flow demand and link capacity values (Table 9 and 10).

Link Utilization = Flow/Demand

Fifth module

Cycle detection: This module is used to detect the occurrence of cycle.Cycle- Set of links repeatedly getting maximum utilization.

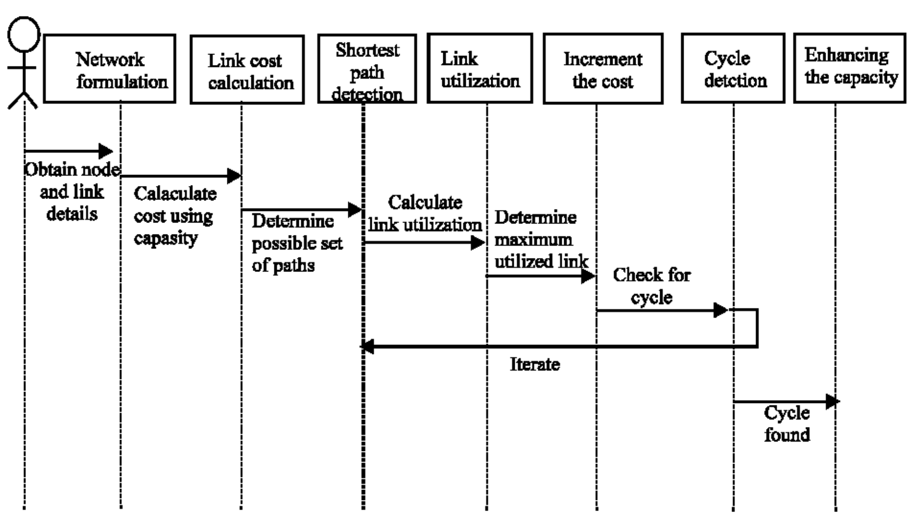

Fig. 5: Sequence diagram

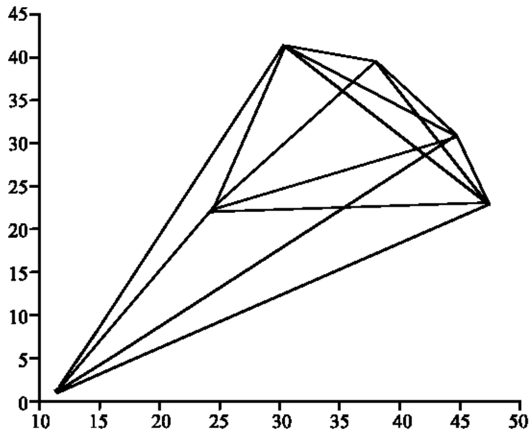

Fig. 6: Snapshot of the network formulation

Table 6: Link capacity matrix

0	30	40	20	15	30
30	0	60	30	25	0
40	60	0	10	30	20
20	30	10	0	10	40
15	25	30	10	0	60
30	0	20	40	60	0

Table 7: Link cost matrix

0	20	15	30	40	20
20	0	10	20	24	0
15	10	0	60	20	30
30	20	60	0	60	15
40	24	20	60	0	10
20	0	30	15	10	0

Table 8: Shortest path with cost

Demand pair	Path	Cost
(1,2)	[1 2]	20
(1,3)	[1 3]	15
(1,4)	[1 4]	30
(1,5)	[1 6 5]	30
(1,6)	[1 6]	20
(2,3)	[2 3]	10
(2,4)	[2 4]	20
(2,5)	[2 5]	24
(2,6)	[2 5 6]	35
(3,4)	[3 2 4]	31
(3,5)	[3 5]	20
(3,6)	[3 6]	30
(4,5)	[4 6 5]	25
(4,6)	[4 6]	15
(5,6)	[5 6]	10

Table 9: Flow demand matrix

0	8	5	12	3	7
8	0	2	11	9	14
5	2	0	3	7	6
12	11	3	0	4	1
3	9	7	4	0	3
7	14	6	1	3	0

Table 10: Link capacity matrix

0	30	40	20	15	30
30	0	60	30	25	0
40	60	0	10	30	20
20	30	10	0	10	40
15	25	30	10	0	60
30	0	20	40	60	0

Iteration 1 and 3:

Table 11: Link cost matrix

0	20	15	30	40	20
20	0	10	20	24	0
15	10	0	60	20	30
30	20	60	0	60	15
40	24	20	60	0	10
20	0	30	15	10	0

Table 12: Link utilization

Link	Flow demand	Capacity	Utilization
1-2	8	30	0.2667
1-3	5	40	0.1250
1-4	12	20	0.6000
1-5	0	15	0
1-6	10	30	0.3333
2-3	5	60	0.0833
2-4	14	30	0.4667
2-5	23	25	0.9200
3-4	0	10	0
3-5	7	30	0.2333
3-6	6	20	0.3000
4-5	0	10	0
4-6	5	40	0.1250
5-6	24	60	0.4000

Iteration 2 and 4:

Table 13 : Link cost matrix

0	20	15	30	40	20
20	0	10	20	25	0
15	10	0	60	20	30
30	20	60	0	60	15
40	24	20	60	0	10
20	0	30	15	10	0

Table 14: Link utilization

Link	Flow demand	Capacity	Utilization
1-2	8	30	0.2667
1-3	5	40	0.1250
1-4	12	20	0.6000
1-5	0	15	0
1-6	10	30	0.3333
2-3	5	60	0.0833
2-4	28	30	0.9333
2-5	9	25	0.3600
3-4	0	10	0
3-5	7	30	0.2333
3-6	6	20	0.3000
4-5	0	10	0
4-6	19	40	0.4750
5-6	10	60	0.1667

In this example the link [2 5] and [2 4] gets maximum utilization repeatedly.
This is the indication of cycle occurrence.

The iteration is repeated until cucyle is detected and it is shown in the following tables.

From the Table 11-14 it can be identified that the cycle is detected on the links[2-4] and [2-5]. The results of the implementation are formulated as table for clear representation.

CONCLUSION

Our study provides a better knowledge to the administrators about the time when a corporate should go for upgradation of link bandwidth of its existing network. An early upgradation means a traffic less network and an timed out upgradation results in customer outrage. So pointing a balanced point in the time map for upgradation is the objective of this study. This has been achieved through a combination of optimal routing technique and identification of cycle between two links. We hope that this study will provide a paradigm for better services at a time when the internet is growing exponentially. In the near future we planned to increase the parameter for identifying the saturation level of network links.

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