CS542 Project **(Spring 2017)**

Traffic routing: Network operator's vs. user's perspective

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Table of Contents

Abstract 3

Quantitative analysis

- Optimal strategy for a network operator . 3
- Optimal strategy for an individual user . 5

Algorithm 6

Technologies Used .. 7

Testing Results 7

Conclusion . 8

Abstract

The objective of this project is to find optimal control variables allocating traffic to various links connecting source S to destination D. We have to take into consideration two cases wherein first case calculates optimal solution for a network operator and second case calculates optimal solution based on user's interest.

Following notations are followed throughout the document.

S - Source router

D - Destination router

A - Allocated traffic to Source S (measured in packets/sec)

c_i - Capacity of link, where i=1,2..n and n=number of links (measured in packets/sec)

a_i - Control variable allocating traffic to link, where i=1,2..n and n=number of links

f_i - Traffic intensity, where i=1,2..n and n=number of links (measured in packets/sec)

f_i can be calculated as,

$f_i = a_i*A$

d_i - Average delay experienced by packets, where i=1,2..n and n=number of links

d_i can be calculated as,

$d_i = 1/(c_i-f_i)$

Quantitative analysis

Optimal strategy for a network operator

Network operator, while making a decision which packet has to be sent over which link, will always take into consideration the average delay introduced by packets.

Hence to calculate delay-related quality criterion $J_n(a_1,a_2,c_1,c_2,A)$ that is best from the network operator's perspective, we consider all the combination of a_1 and a_2 where $0<=a_1<=1$ and $0<=a_2<=1$. All these combinations of a_1 and a_2 should match following criterion,

$a_1+a_2=1;$

Traffic intensity allocated to each link (for each a_1,a_2 combination) can be calculated as,

$f1=a1*A$ and $f2=a2*A$

Let d1 be the delay of link1 and d2 be the delay of link2. d1 and d2 can be calculated as,

$d1=1/(c1-f1)$ and $d2=1/(c2-f2)$

So for each (a1, a2) combination we have a (d1,d2) combination. We have to find out that one combination which introduces minimum delay for both links.

Therefore, delay-related quality criterion Jn(a1,a2,c1,c2,A) can be defined best from network operator's perspective as,

$Jn = \min\{ (d1+d2)$

Example

Let s assume A=10, c1=16, c2=4.

Let a1 = 0/100,1/100,....,100/100

f1 = a1*A

Therefore, f1 = 0,0.1,....,10

Similarly, f2 = 10,9.9,....,0

So if delay is calculated for each such combination, the total minimum delay will result for f1=10 and f2=0. Delay incurred will be,

d1 = 1/(c1-f1)=1/(16-10) = 0.17

d2 = 0 as no packets are transferred through this link.

Optimal strategy for an individual user

User, while making a decision which packet has to be sent over which link, will always take into consideration the average delay introduced by a packet.

Hence to calculate delay-related quality criterion Jp(a1,a2,a3,c1,c2,c3,A) which is best from individual user's perspective, we will have to consider delay incurred by each packet.

We consider all the combination of a1, a2 and a3 where 0<=a1<=1, 0<=a2<=1, 0<=a3<=1. All these combinations of a1,a2 and a3 should match following criterion,

a1+a2+a3=1;

Traffic intensity allocated to each link can be calculated (for each a1,a2,a3 combination) as,

f1=a1*A; f2=a2*A; f3=a3*A

Delay introduced for link1, link2 and link3 can be calculated as,

d1=1/(c1-f1); d2=1/(c2-f2); d3=1/(c3-f3)

So for each (a1,a2,a3) combination we have a (d1,d2,d3) combination. We have to find out that one combination which introduces minimum total delay i.e. (d1+d2+d3).

Therefore, delay-related quality criterion Jp(a1,a2,a3,c1,c2,c3,A) which is best from individual user's perspective can be defined as,

$$Jp = \min \{(d1+d2+d3)$$

<u>Example</u>

Let s assume A=20, c1=16, c2=4, c3=6.

Let a1 = 0/100,1/100,....,100/100

f1 = a1*A

Therefore, f1 = 0,0,....,20

Similarly,

f2 = 20,0,....,0

f3 = 0,20,....,0

}

So if delay is calculated for each such combination, the total minimum delay will result for f1=14 and f2=2 and f3=4.

Delay incurred will be,

$d_1 = 1/(c_1-f_1)=1/(16-14) = 0.5$

$d_2 = 1/(c_2-f_2)=1/(4-2) = 0.5$

$d_3 = 1/(c_3-f_3)=1/(6-4) = 0.5$

Hence total delay=1.5 which is minimum.

Algorithm:

We assume that an average delay experienced by a packet is $d=1/(c-f)$, where c denotes capacity of a link and f is intensity of traffic offered to this link.

The Pseudo code for the Algorithm implemented by us is as follows.

```
For every combination of (a1,a2,a3,..ai)                    // where i=number of links
 {
  while (a1+a2+..ai === 100)
        {
calculate traffic intensity for each link using formula (f1..i)=((a1..i/100)*A);
            if traffic intensity for each link is less than the capacity
                  {
                  calculate delay for each link using formula (d1..i)=1/((c1..i)-(f1..i));
                  if the delay is less than previous delay
                        {
                        get the values of (a1..i);
                        }
                  }
        }
}
```

Technologies Used:

C programming is used for the implementation.

Testing Results:

- For network operator, A=10, c1=16 and c2=4

```
C:\TURBOC3\BIN>TC
Please input allocated traffic (A): 10
Please input capacity of route 1 (c1): 16
Please input capacity of route 2 (c2): 4

Fetching result for network operator...
Control variable a1 = 1.00
Control variable a2 = 0.00
Total Delay = 0.17
```

- For individual user, A=20, c1=16, c2=4 and c3=6

```
C:\TURBOC3\BIN>TC
Please input allocated traffic (A): 20
Please input capacity of route 1 (c1): 16
Please input capacity of route 2 (c2): 4
Please input capacity of route 3 (c3): 6

Fetching result for a user...
Control variable a1 = 0.70
Control variable a2 = 0.10
Control variable a3 = 0.20
Total Delay = 1.50
```

Conclusion:

An individual user will go for a link whose utilization is less and whose delay is minimum but since we are not suppose to take into account the link utilization and other costs, there is only one criterion to consider i.e, delay. Therefore both network operator and user have to try to minimize the delay using the same quality criterion. Hence to conclude, delay related quality criterion for both Network Operator's perspective and User's perspective are identical.