

COSC364

Assignment 2



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**Percentage Contribution**

Kate 50

Shan 50

**Problem Formulation and Explanation**

The objective of the assignment is to minimize the maximum link utilization also known as load balancing. To do this we introduce and auxiliary variable to represent the value of our objective. The demand volume, , of all path between a source node and a destination node for all is stated as = + as shown in equation (1) and (7). There is a global requirement that each demand volume shall be split equally over exactly 3 different paths hence we use a binary variable where if the path - - is used to carry the flow then the value of else . We use this variable to determine that the sum of all flow from source to destination for all transit node are split into 3 different paths as in equation (2) while equation (3) ensures that the splits are done equally. Next, equation (4) and equation (5) defines the constraint that the sum of all flows using the path - for all destination is less than or equal to the link capacity, and the sum of all flows using the path - for all destination is less than or equal to the link capacity, respectively. We then check that the sum of flow through transit node for all and is less than the auxiliary variable . Equation (8) defines as a binary variable while Equation (9) – (12) describes that the variables are of non-negative values.

Link utilization is defined as the total flow on a link divided by the capacity of the link.

|  |  |  |
| --- | --- | --- |
| **Minimize [x, r]** |  |  |
| **Subject to** |  | ……….. (1) |
|  |  | ……….. (2) |
|  |  | ……….. (3) |
|  |  | ……….. (4) |
|  |  | ……….. (5) |
|  |  | ……….. (6) |
|  |  | ……….. (7) |
|  |  | ……….. (8) |
|  |  | ……….. (9) |
|  |  | ….….. (10) |
|  |  | ….….. (11) |
|  |  | .…….. (12) |

**CPLEX execution time, numbers of non-zero capacity links and the highest capacity link for varying Y**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| # of Transit Nodes | 3 | 4 | 5 | 6 | 7 |
| Load | 130.666667 | 98 | 78.666667 | 65.333333 | 56 |
| CPLEX execution time | 0.0285 | 0.0529 | 0.0634 | 0.1202 | 0.1634 |
| # of non-zero capacity links | 42 | 56 | 69 | 82 | 94 |
| Highest capacity link | 25.666667 | 23.333333 | 21.666667 | 23 | 19 |

**Appendix I – Source Code**

**Appendix II – LP file generated for (X = 3, Y = 2, Z = 4)**

Minimize

r

Subject to

rT1: xS1T1D1 + xS1T1D2 + xS1T1D3 + xS1T1D4 + xS2T1D1 + xS2T1D2 + xS2T1D3 + xS2T1D4 + xS3T1D1 + xS3T1D2 + xS3T1D3 + xS3T1D4 - r <= 0

rT2: xS1T2D1 + xS1T2D2 + xS1T2D3 + xS1T2D4 + xS2T2D1 + xS2T2D2 + xS2T2D3 + xS2T2D4 + xS3T2D1 + xS3T2D2 + xS3T2D3 + xS3T2D4 - r <= 0

hS1D1: xS1T1D1 + xS1T2D1 = 2

hS1D2: xS1T1D2 + xS1T2D2 = 3

hS1D3: xS1T1D3 + xS1T2D3 = 4

hS1D4: xS1T1D4 + xS1T2D4 = 5

hS2D1: xS2T1D1 + xS2T2D1 = 3

hS2D2: xS2T1D2 + xS2T2D2 = 4

hS2D3: xS2T1D3 + xS2T2D3 = 5

hS2D4: xS2T1D4 + xS2T2D4 = 6

hS3D1: xS3T1D1 + xS3T2D1 = 4

hS3D2: xS3T1D2 + xS3T2D2 = 5

hS3D3: xS3T1D3 + xS3T2D3 = 6

hS3D4: xS3T1D4 + xS3T2D4 = 7

dfS1T1D1: 3 xS1T1D1 - 2 uS1T1D1 = 0

dfS1T2D1: 3 xS1T2D1 - 2 uS1T2D1 = 0

dfS1T1D2: 3 xS1T1D2 - 3 uS1T1D2 = 0

dfS1T2D2: 3 xS1T2D2 - 3 uS1T2D2 = 0

dfS1T1D3: 3 xS1T1D3 - 4 uS1T1D3 = 0

dfS1T2D3: 3 xS1T2D3 - 4 uS1T2D3 = 0

dfS1T1D4: 3 xS1T1D4 - 5 uS1T1D4 = 0

dfS1T2D4: 3 xS1T2D4 - 5 uS1T2D4 = 0

dfS2T1D1: 3 xS2T1D1 - 3 uS2T1D1 = 0

dfS2T2D1: 3 xS2T2D1 - 3 uS2T2D1 = 0

dfS2T1D2: 3 xS2T1D2 - 4 uS2T1D2 = 0

dfS2T2D2: 3 xS2T2D2 - 4 uS2T2D2 = 0

dfS2T1D3: 3 xS2T1D3 - 5 uS2T1D3 = 0

dfS2T2D3: 3 xS2T2D3 - 5 uS2T2D3 = 0

dfS2T1D4: 3 xS2T1D4 - 6 uS2T1D4 = 0

dfS2T2D4: 3 xS2T2D4 - 6 uS2T2D4 = 0

dfS3T1D1: 3 xS3T1D1 - 4 uS3T1D1 = 0

dfS3T2D1: 3 xS3T2D1 - 4 uS3T2D1 = 0

dfS3T1D2: 3 xS3T1D2 - 5 uS3T1D2 = 0

dfS3T2D2: 3 xS3T2D2 - 5 uS3T2D2 = 0

dfS3T1D3: 3 xS3T1D3 - 6 uS3T1D3 = 0

dfS3T2D3: 3 xS3T2D3 - 6 uS3T2D3 = 0

dfS3T1D4: 3 xS3T1D4 - 7 uS3T1D4 = 0

dfS3T2D4: 3 xS3T2D4 - 7 uS3T2D4 = 0

cS1T1: xS1T1D1 + xS1T1D2 + xS1T1D3 + xS1T1D4 - yS1T1 = 0

cS1T2: xS1T2D1 + xS1T2D2 + xS1T2D3 + xS1T2D4 - yS1T2 = 0

cS2T1: xS2T1D1 + xS2T1D2 + xS2T1D3 + xS2T1D4 - yS2T1 = 0

cS2T2: xS2T2D1 + xS2T2D2 + xS2T2D3 + xS2T2D4 - yS2T2 = 0

cS3T1: xS3T1D1 + xS3T1D2 + xS3T1D3 + xS3T1D4 - yS3T1 = 0

cS3T2: xS3T2D1 + xS3T2D2 + xS3T2D3 + xS3T2D4 - yS3T2 = 0

dT1D1: xS1T1D1 + xS2T1D1 + xS3T1D1 - yT1D1 = 0

dT2D1: xS1T2D1 + xS2T2D1 + xS3T2D1 - yT2D1 = 0

dT1D2: xS1T1D2 + xS2T1D2 + xS3T1D2 - yT1D2 = 0

dT2D2: xS1T2D2 + xS2T2D2 + xS3T2D2 - yT2D2 = 0

dT1D3: xS1T1D3 + xS2T1D3 + xS3T1D3 - yT1D3 = 0

dT2D3: xS1T2D3 + xS2T2D3 + xS3T2D3 - yT2D3 = 0

dT1D4: xS1T1D4 + xS2T1D4 + xS3T1D4 - yT1D4 = 0

dT2D4: xS1T2D4 + xS2T2D4 + xS3T2D4 - yT2D4 = 0

uS1D1: uS1T1D1 + uS1T2D1 = 3

uS1D2: uS1T1D2 + uS1T2D2 = 3

uS1D3: uS1T1D3 + uS1T2D3 = 3

uS1D4: uS1T1D4 + uS1T2D4 = 3

uS2D1: uS2T1D1 + uS2T2D1 = 3

uS2D2: uS2T1D2 + uS2T2D2 = 3

uS2D3: uS2T1D3 + uS2T2D3 = 3

uS2D4: uS2T1D4 + uS2T2D4 = 3

uS3D1: uS3T1D1 + uS3T2D1 = 3

uS3D2: uS3T1D2 + uS3T2D2 = 3

uS3D3: uS3T1D3 + uS3T2D3 = 3

uS3D4: uS3T1D4 + uS3T2D4 = 3

Bounds

xS1T1D1 >= 0

xS1T2D1 >= 0

xS1T1D2 >= 0

xS1T2D2 >= 0

xS1T1D3 >= 0

xS1T2D3 >= 0

xS1T1D4 >= 0

xS1T2D4 >= 0

xS2T1D1 >= 0

xS2T2D1 >= 0

xS2T1D2 >= 0

xS2T2D2 >= 0

xS2T1D3 >= 0

xS2T2D3 >= 0

xS2T1D4 >= 0

xS2T2D4 >= 0

xS3T1D1 >= 0

xS3T2D1 >= 0

xS3T1D2 >= 0

xS3T2D2 >= 0

xS3T1D3 >= 0

xS3T2D3 >= 0

xS3T1D4 >= 0

xS3T2D4 >= 0

yS1T1 >= 0

yS1T2 >= 0

yS2T1 >= 0

yS2T2 >= 0

yS3T1 >= 0

yS3T2 >= 0

yT1D1 >= 0

yT2D1 >= 0

yT1D2 >= 0

yT2D2 >= 0

yT1D3 >= 0

yT2D3 >= 0

yT1D4 >= 0

yT2D4 >= 0

r >= 0

Binaries

uS1T1D1

uS1T2D1

uS1T1D2

uS1T2D2

uS1T1D3

uS1T2D3

uS1T1D4

uS1T2D4

uS2T1D1

uS2T2D1

uS2T1D2

uS2T2D2

uS2T1D3

uS2T2D3

uS2T1D4

uS2T2D4

uS3T1D1

uS3T2D1

uS3T1D2

uS3T2D2

uS3T1D3

uS3T2D3

uS3T1D4

uS3T2D4

End