**COSC 364**

**Internet Technologies and Engineering**

**Second Assignment**

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The percentage contribution:

**Kyran Stagg 50%**

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Our problem formulation and explanation for this:

1. The objective function:

1. The decision variables:

* 𝑥𝑖𝑘 referring to the part of the demand volume between source node *i* and destination node *j* that is routed through transit node *k.*

1. All constraints:

* Constraints 1:

𝑥𝑖𝑘𝑗=ℎ𝑖𝑗

Explanation: The sum of the amounts of all flows which the part of the demand volume between source node *i* and destination node *j* that is routed the path through transit node *k* equal to ℎ𝑖𝑗 .

* Constraints 2:

𝑢𝑖𝑘𝑗=𝑛𝑖𝑗

Explanation: Because each flow 𝑥𝑖𝑘𝑗  must be positive for exactly two values *k1*, *k2* (i.e. 𝑥𝑖𝑘𝑗  > 0 and 𝑥𝑖𝑘𝑗  > 0) and must be zero for all other *k*, the 𝑛𝑖𝑗 is equal to 2. The binary indicator variables 𝑢𝑖𝑘𝑗 ∈ {0,1} and when the path through transit node *k*-th of demand volume is used, it is equal to 1, otherwise it is equal to 0. So that every sum of 𝑢𝑖𝑘𝑗  for every *k* is equal to 𝑛𝑖𝑗.

* Constraints 3:

𝑥𝑖𝑘𝑗 𝑐𝑖𝑘

Explanation: For a link between source node *Si* and transit node *Tk* we denote its capacity by 𝑐𝑖𝑘. Every flow 𝑥𝑖𝑘𝑗  of all paths must be less than or equal to the link capacity 𝑐𝑖𝑘 between source node and transit node.

* Constraints 4:

𝑥𝑖𝑘𝑗 𝑑𝑘𝑗

Explanation: For a link between transit node *Tk* and destination node *Dj* we denote its capacity by 𝑑𝑘𝑗. Every flow 𝑥𝑖𝑘𝑗  of all paths must be less than or equal to the link capacity 𝑑𝑘𝑗 between transit node and destination node.

* Constraints 5:

𝑥𝑖𝑘𝑗 = 𝑢𝑖𝑘𝑗 \*

Explanation: When the binary indicator variable 𝑢𝑖𝑘𝑗 is equal to 1, each flow 𝑥𝑖𝑘𝑗 is equal to the demand volume ℎ𝑖𝑗 split over exactly two different paths .

* Constraints 6:

Explanation: The auxiliary variable represents the value at least as the maximum of the flow 𝑥𝑖𝑘𝑗 through all links. By minimizing then we automatically also minimize the load on all transit nodes.

1. Bounds: Non-negativity constraints

𝑥𝑖𝑘𝑗

𝑐𝑖𝑘

𝑑𝑘𝑗

Explanation: The path flow 𝑥𝑖𝑘𝑗 , the link capacity 𝑐𝑖𝑘 between source node and transit node and the link capacity 𝑑𝑘𝑗 between transit node and destination node must be non-negativity , as negative data rates make no sense.

1. Binary list:

* 𝑢𝑖𝑘𝑗  The binary indicator variables 𝑢𝑖𝑘𝑗 ∈ {0,1}. When the path through transit node *k*-th of demand volume is used, it is equal to 1, otherwise it is equal to 0.

The results for the CPLEX execution time, the number of links with non-zero capacities, the spread of transit node loads (i.e. the difference between the largest and the smallest transit node load), and the highest-capacity links, all for varying Y . Show these results as a graph or as a table. Please explain your results.

The source code of your program as an appendix:

A generated LP file (for X = 3, Y = 2 and Z = 4) as an appendix:

Minimize

r

Subject to

x111 + x121 = 3

x112 + x122 = 4

x113 + x123 = 5

x114 + x124 = 6

x211 + x221 = 5

x212 + x222 = 6

x213 + x223 = 7

x214 + x224 = 8

x311 + x321 = 7

x312 + x322 = 8

x313 + x323 = 9

x314 + x324 = 10

u111 + u121 = 2

u112 + u122 = 2

u113 + u123 = 2

u114 + u124 = 2

u211 + u221 = 2

u212 + u222 = 2

u213 + u223 = 2

u214 + u224 = 2

u311 + u321 = 2

u312 + u322 = 2

u313 + u323 = 2

u314 + u324 = 2

x111 + x112 + x113 + x114 - c11 <= 0

x121 + x122 + x123 + x124 - c12 <= 0

x211 + x212 + x213 + x214 - c21 <= 0

x221 + x222 + x223 + x224 - c22 <= 0

x311 + x312 + x313 + x314 - c31 <= 0

x321 + x322 + x323 + x324 - c32 <= 0

x111 + x211 + x311 - d11 <= 0

x112 + x212 + x312 - d12 <= 0

x113 + x213 + x313 - d13 <= 0

x114 + x214 + x314 - d14 <= 0

x121 + x221 + x321 - d21 <= 0

x122 + x222 + x322 - d22 <= 0

x123 + x223 + x323 - d23 <= 0

x124 + x224 + x324 - d24 <= 0

2 x111 - 3 u111 = 0

2 x112 - 4 u112 = 0

2 x113 - 5 u113 = 0

2 x114 - 6 u114 = 0

2 x121 - 3 u121 = 0

2 x122 - 4 u122 = 0

2 x123 - 5 u123 = 0

2 x124 - 6 u124 = 0

2 x211 - 5 u211 = 0

2 x212 - 6 u212 = 0

2 x213 - 7 u213 = 0

2 x214 - 8 u214 = 0

2 x221 - 5 u221 = 0

2 x222 - 6 u222 = 0

2 x223 - 7 u223 = 0

2 x224 - 8 u224 = 0

2 x311 - 7 u311 = 0

2 x312 - 8 u312 = 0

2 x313 - 9 u313 = 0

2 x314 - 10 u314 = 0

2 x321 - 7 u321 = 0

2 x322 - 8 u322 = 0

2 x323 - 9 u323 = 0

2 x324 - 10 u324 = 0

x111 + x112 + x113 + x114 + x211 + x212 + x213 + x214 + x311 + x312 + x313 + x314 - r <= 0

x121 + x122 + x123 + x124 + x221 + x222 + x223 + x224 + x321 + x322 + x323 + x324 - r <= 0

Bounds

x111 >= 0

x112 >= 0

x113 >= 0

x114 >= 0

x121 >= 0

x122 >= 0

x123 >= 0

x124 >= 0

x211 >= 0

x212 >= 0

x213 >= 0

x214 >= 0

x221 >= 0

x222 >= 0

x223 >= 0

x224 >= 0

x311 >= 0

x312 >= 0

x313 >= 0

x314 >= 0

x321 >= 0

x322 >= 0

x323 >= 0

x324 >= 0

c11 >= 0

c12 >= 0

c21 >= 0

c22 >= 0

c31 >= 0

c32 >= 0

d11 >= 0

d12 >= 0

d13 >= 0

d14 >= 0

d21 >= 0

d22 >= 0

d23 >= 0

d24 >= 0

Binary

u111

u112

u113

u114

u121

u122

u123

u124

u211

u212

u213

u214

u221

u222

u223

u224

u311

u312

u313

u314

u321

u322

u323

u324

End

The signed plagiarism declaration: