TSP Integer Programming

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All problems are related to the graph below. Black edges have weight 1, and red edges have weight 2.

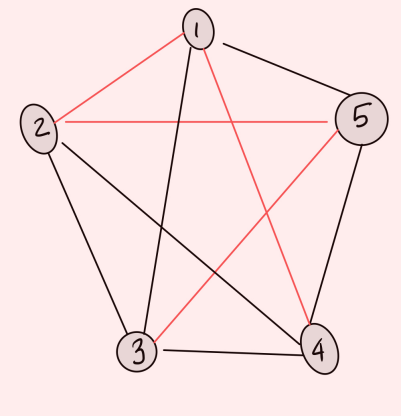

Figure 1: TSP instance

Problem 1

▷ Setting the variable $x_{i,j} = 1$ denotes that we go from vertex i to j using the edge (i, j) in our tour.
▷ The constraint $x_{2,1} + x_{3,1} + x_{4,1} + x_{5,1} = 1$ expresses that we have exactly one edge entering the vertex 1 in our tour.

Problem 2

▷ Time stamp variables t_2, t_3, t_4, t_5 are added to eliminate possible subtours by assigning increasing time stamps to nodes visited along a tour.
▷ The constraint $t_3 \geq t_2 + x_{2,3} - M(1 - x_{2,3})$ for a large number M is equivalent to if $(x_{2,3} = 1)$ then $t_3 \geq t_2 + 1$ else $t_3 \geq t_2 - M$.

Problem 3

▷ $x_{2,4} + x_{3,4} + x_{5,4} + x_{2,1} + x_{3,1} + x_{5,1} \geq 1$
▷ $x_{4,2} + x_{4,3} + x_{4,5} + x_{1,2} + x_{1,3} + x_{1,5} \geq 1$