Course: Telecommunication Network Design
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1 Discrete Programming Problems

1.1 Optimization problems with discrete variables

1. Integer (Linear) Programming (IP/ILP):
   - max $\mathbf{cx}$,
   - s.t.:
     - ⋆ $\mathbf{Ax} \leq \mathbf{b}$ (linear constraints),
     - ⋆ $\mathbf{x} \geq \mathbf{0}$,
     - ⋆ $\mathbf{x} \in \mathbb{Z}$ (integrality constraints).
2. Mixed Integer (Linear) Programming (MIP/MILP):
   - max $\mathbf{cx} + \mathbf{dy}$,
   - s.t.:
     - ⋆ $\mathbf{Ax} + \mathbf{Dy} \leq \mathbf{b}$ (linear constraintse),
     - ⋆ $\mathbf{x}, \mathbf{y} \geq \mathbf{0}$,
     - ⋆ $\mathbf{y} \in \mathbb{R}$,
     - ⋆ $\mathbf{x} \in \mathbb{Z}$ (integrality constraints).

1.2 Exercises

1. A fragment of an optimization problem related to resource and flow allocation satisfying some network demands is given below:
   - Indices:
     - ⋆ $e = 1, 2, \ldots, E$ edges;
     - ⋆ $v = 1, 2, \ldots, V$ nodes;
     - ⋆ $d = 1, 2, \ldots, D$ demands.
   - Constants:
     - ⋆ a_{ev} binary value.
   - Variables:
     - ⋆ u_{ed} binary variable;
     - ⋆ w_{ed} binary variable;
     - ⋆ x_{ed} non-negative integer variable;

  - ⋆ z_{ed} non-negative integer variable;
  - ⋆ y_{ed} non-negative integer variable.
- Constraints:
  - ⋆ $w_{ed}u_{ed} > 0$ $e = 1, 2, \ldots, E$, $d = 1, 2, \ldots, D$;
  - ⋆ a_{ev} XOR $u_{ed} < 1$ $e = 1, 2, \ldots, E$, $v = 1, 2, \ldots, V$, $d = 1, 2, \ldots, D$;
  - ⋆ $\frac{x_{ed}}{y_{ed}+z_{ed}} = 49$ $e = 1, 2, \ldots, E$, $d = 1, 2, \ldots, D$;
  - ⋆ $x_{ed}y_{ed} \geq 2$ $e = 1, 2, \ldots, E$, $d = 1, 2, \ldots, D$

This formulation meant to be a fragment of a mixed integer linear programming MILP problem. But it is not (say, why?). Correct this formulation, so that without changing the meaning, it is a proper MILP formulation indeed (do not focus on the formulation sense, but only on its modeling correctness).