Results. Due to the size of the resulting models, the MILP models are extremely difficult to solve. The best LP solver appears to be the barrier method in Cplex, which nevertheless runs out of memory for the larger instance.

The tables below show the results obtained for the three models on four instances:

– `pacbell`: 14-node topology, found in [1];
– `njlata`: 11 nodes and 23 links, respectively, found in [3];
– `metro`: 11-node metropolitan network of Stockholm [4];
– `nor_sun`: 27-node network found in [2].

The parameters of each instance are shown in Table 1: size of the network ($|V|$ and $|A|$), number of demands ($|Q|$), and, for each model, the number of variables, integer variables, and constraints.

				MILP-1			MILP-2			MINLP		
Name	$\|V\|$	$\|A\|$	$\|Q\|$	var	int	con	var	int	con	var	int	con
`pacbell`	15	42	42	40614	3528	40068	40614	40572	53298	3570	3570	3024
`njlata`	11	46	56	77326	5152	62826	77326	77280	76994	5198	5198	3578
`metro`	11	84	25	30534	4200	93328	30534	30450	104878	4284	4284	5128
`nor_sun`	27	102	156	1273062	31824	833094	1273062	1272960	1047906	31926	31926	21582

Table 1. Size of the instances.

Table 2 below instead reports on the computational tests performed with the two MILP models. MILP-1 and MILP-2 have been solved using an Intel Xeon 3.2GHz CPU with 2.5GB of RAM and Cplex 12 as the MILP solver. The MINLP model has been attacked with Couenne[1]. For each model, the time (t) and best solution found (ub) are reported if the former is below the limit of two hours, otherwise the optimality gap (or the lower bound if no upper bound is found) is provided in brackets. Although the MINLP model is far smaller than the number of variables and constraints, none of the MINLP instances could solved with Couenne, which is unable to find a lower bound for the continuous relaxation.

	MILP-1		MILP-2	
Name	t (lb)	ub	t (lb)	ub
`pacbell`	1145	353410	(294738)	–
`njlata`	(7.7%)	1058190	(905097)	–
`metro`	(22.3%)	9690000	(7119600)	–
`nor_sun`	(142931)	–	(149074)	–

Table 2. Solution found with the three models.

[1] See https://projects.coin-or.org/Couenne

Given that the size of the MILP models may increase with $|V|^6$, this problem is very difficult to solve even for mid-size networks. The four instances provided for each model are of different difficulty: the first, `pacbell`, is relatively easy as it can be solved to integer optimality for the first MILP models by Cplex 12. The other instances correspond to larger networks and prove difficult for Cplex. Although the second MILP model seems tighter as it includes flow constraints for the extra variables Z, its linear relaxation is still too large to be solved within two hours.

The results show that both linear and nonlinear models are insufficient to solve this network design problem. Ad hoc methods have to be devised in order to tackle mid-size instances.

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