Multi-skilled workforce management

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Motivation for advanced scheduling

Advanced scheduling in France Télécom

- Steadily increasing number of services.

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Basic concepts in scheduling data

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  - *Minimize* the weighted makespan

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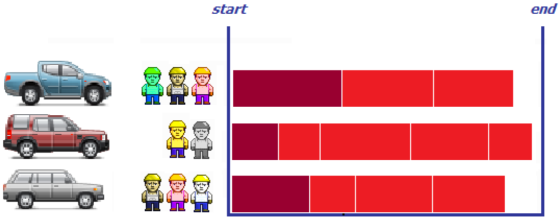
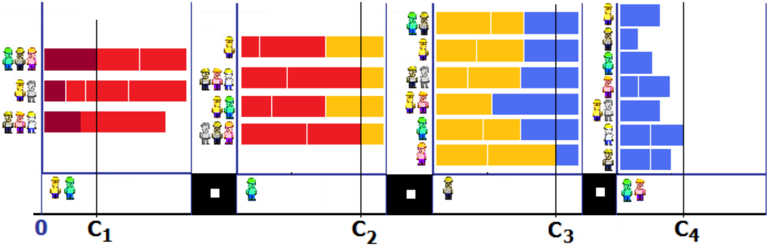
- So, use the team $\tau = \{t_1, t_2\}$!

A workday schedule



A complete schedule



The schedule cost is the weighted makespan: $\sum_i w_i C_i$.

How hard is to solve our scheduling problem?

Theoretical result

Theorem 1

Technician scheduling problem of France Télécom is NP-Hard in the strong sense.[1]

[1] *Stable multi-skill workforce assignments*, Fırat, M., Hurkens, C., Laugier, A., 2014, Annals of OR.

Benchmark instances[2]

	Data set A				Data set B				Data set X			
Ins.	$\|T\|$	$\|J\|$	$\|D\|$	$\|L\|$	$\|T\|$	$\|J\|$	$\|D\|$	$\|L\|$	$\|T\|$	$\|J\|$	$\|D\|$	$\|L\|$
1	5	5	3	2	20	200	4	4	60	600	15	4
2	5	5	3	2	30	300	5	3	100	800	6	6
3	7	20	3	2	40	400	4	4	50	300	20	3
4	7	20	4	3	30	400	40	3	70	800	15	7
5	10	50	3	2	50	500	7	4	60	600	15	4
6	10	50	5	4	30	500	8	3	20	200	6	6
7	20	100	5	4	100	500	10	5	50	300	20	3
8	20	100	5	4	150	800	10	4	30	100	15	7
9	20	100	5	4	60	120	5	5	50	500	15	4
10	15	100	5	4	40	120	5	5	40	500	15	4

[2] *Technicians and interventions scheduling for telecommunications*, France Télécom R&D, Orange Labs.

What about formulating as a MILP model?

An experimentation[3] reports

> After 24-hour computation time, instances $A3$ and $A4$ could not be solved by CPLEX 11, leaving optimality gaps 20% and 15% respectively.

[3] *Scheduling technicians and tasks in a telecommunication company*, Cordeau, J. F., Laporte, G., Pasin F., Ropke, S., 2010, Journal of Scheduling.

State-of-art approaches to our scheduling problem

Adapted Large Neighborhood search [4]

- A construction heuristic for initial schedule:

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- Within timelimit: Make restarts of the schedule modification.

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High-Performance local search heuristic[5]

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- Some bookkeeping for maintaining precedence relations.

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- The above decisions are simultaneously made by a flexible Matching model!

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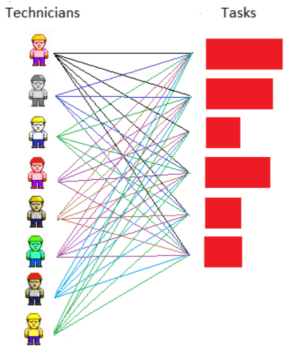
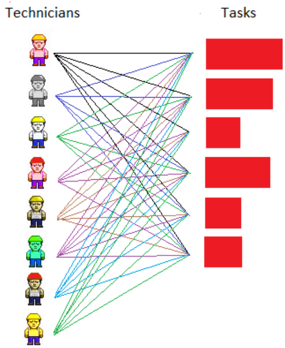
Initial Matching Model (IMM)

IMM: Bipartite Graph

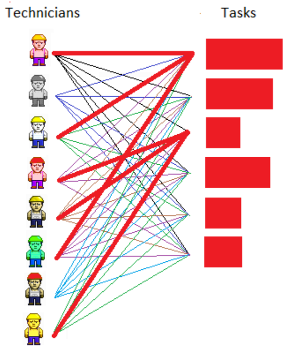


IMM: Matching constraints

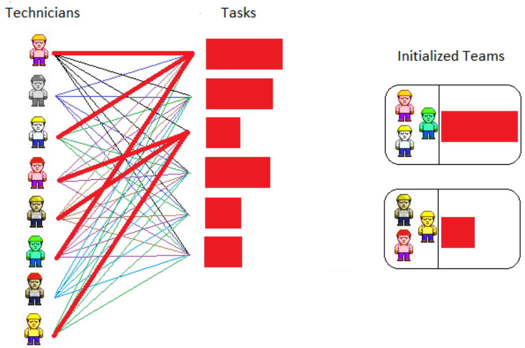


- Technicians match to at most one task.
- Tasks can be matched to any #technicians
- Technicians matched to one task should cumulatively meet skill requirements
- Objective: Maximize weighted sum of matched tasks.

IMM: Matching solution



IMM: Initialized teams



FMM Approach

Matching weights of tasks are sum of the following criteria

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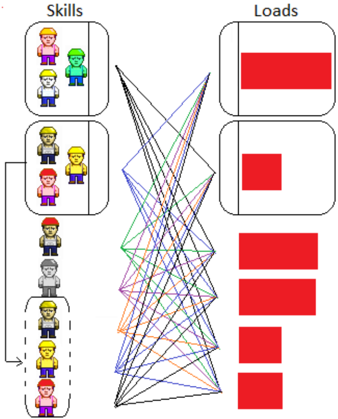
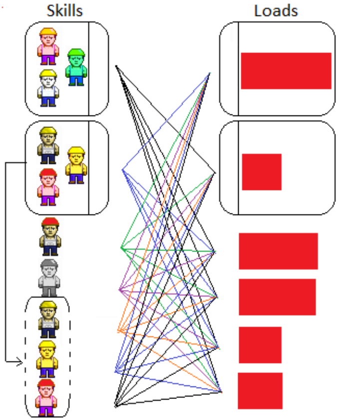


FMM: Matching skills or loads of teams

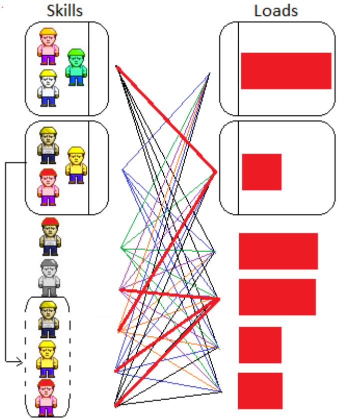


- Either the skill or the load of a team can be matched in a solution.

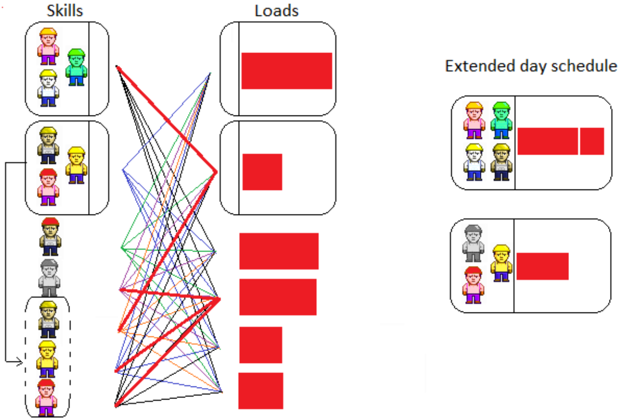
- Matching of the skill of a team results in extension of the load of that team.

- Matching of the load of a team results in releasing the conditionally available technicians of that team.

FMM: Matching solution



FMM: Extended day schedule



Computational Results: Set A

Instance	FMM	(%)	Cordeau	(%)	EsGaNo	(%)	BEST*	LB
A1	2340	0.0	2340	0.0	2340	0.0	2340	2310
A2	4755	0.0	4755	0.0	4755	0.0	4755	2100
A3	11880	0.0	11880	0.0	11880	0.0	11880	11340
A4	13452	0.0	13452	0.0	14040	4.4	13452	10680
A5	29355	1.8	29355	1.8	29400	1.9	28845	26940
A6	20055	6.7	18795	0.0	18795	0.0	18795	17640
A7	30960	1.4	30540	0.0	30540	0.0	30540	28672
A8	17355	2.6	17700	4.6	20100	18.8	16920	16216
A9	28280	3.4	27692	1.3	27440	0.3	27348	25558
A10	39300	2.6	38636	0.9	38460	0.4	38296	36992
Average		*1.8*		*0.9*		*2.6*		

Computational Results: Set B

Instance	FMM	(%)	Cordeau	(%)	EsGaNo	(%)	BEST*	LB
B1	34575	2.0	37200	9.7	33900	0.0	33900	31875
B2	16755	5.6	17070	7.6	16260	2.5	15870	14280
B3	16275	1.7	18015	12.6	16005	0.0	16005	13965
B4	23925	0.6	23775	0.0	24330	2.3	23775	16800
B5	88920	0.3	117540	32.5	88680	0.0	88680	79530
B6	28785	5.1	27390	0.0	27675	1.0	26955	24180
B7	31620	0.0	33900	7.2	36900	16.7	31620	25290
B8	35520	10.4	33240	3.4	36840	14.6	32160	31890
B9	28080	0.0	29760	6.0	32700	16.5	28080	25680
B10	35040	1.0	35640	1.7	41280	19.0	34680	32370
Average		*2.7*		*8.1*		*7.3*		

Computational Results: Set X

Instance	FMM	(%)	Cordeau	(%)	EsGaNo	(%)	BEST*	LB
X1	146220	0.0	159300	8.9	180240	23.3	146220	136680
X2	7740	6.6	8280	14.0	8370	15.3	7260	5700
X3	48720	0.0	50400	3.4	50760	4.2	48720	36060
X4	64600	0.0	66780	3.4	68960	6.7	64600	58230
X5	144750	0.0	157800	9.0	178560	23.4	144750	130995
X6	9690	2.2	9900	4.4	10440	10.1	9480	6150
X7	32040	0.0	47760	49.1	38400	19.9	32040	25410
X8	23220	0.0	24060	3.6	23800	2.5	23220	17600
X9	122700	0.0	152400	24.2	154920	26.3	122700	98805
X10	120300	0.0	140520	16.8	152280	26.6	120300	87210
Average		*0.9*		*13.7*		*15.8*		

Further scheduling topics

Stability in multi-skilled workforce assignments

- The notion of stability in workforce assignments is defined[7].

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Scheduling and Information Systems

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- defining adaptively how an object is “good” is crucial

Thanks